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SOLID WASTE SOURCE SEPARATION EXPERIMENT NCBC, PORT HUENEME.(U)
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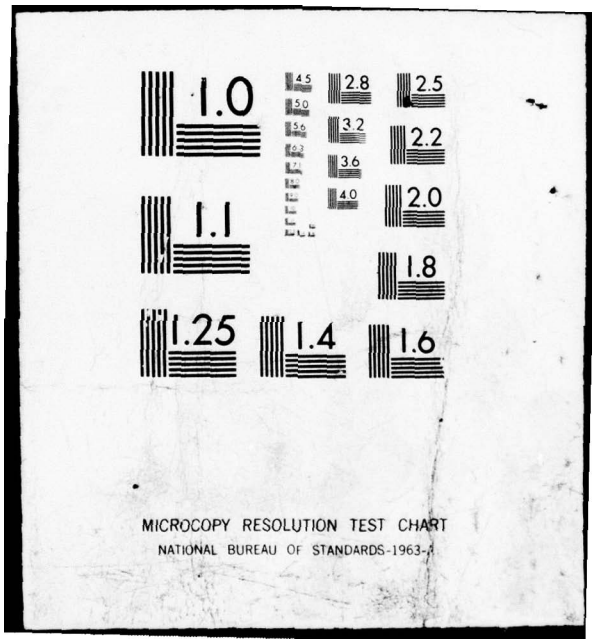
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NAVAL CONSTRUCTION BATTALION CENTER
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Recently promulgated EPA guidelines on solid waste source separation, mandatory for Federal agencies, have placed a high priority on the test and evalution of alternative approaches and of additional costs attributable to source separation. A four-month long test at the Naval Construction Battalion Center, Port Hueneme, California, called for base-wide voluntary source separation of solid waste into two categories during 1976. The test

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was oriented toward waste heat recovery from the combustibles (for steam generation) which, although at odds with the EPA guidelines for source separation, is in the best interest of energy conservation since Navy shore facilities typically use steam for base heating needs. Considered a successful test, indicating the workability and cost-effectiveness of source separation, it generated a large amount of information on the various technical, cost and human factors associated with source separation.

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1. Solid waste management 2. Source separation I. Y41-21-006-01-001

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INTRODUCTION

The Civil Engineering Laboratory (CEL), under a task assignment by the Naval Facilities Engineering Command, undertook an effort to design, conduct and evaluate a solid waste source segregation experiment at the Naval Construction Battalion Center (NCBC), Port Hueneme, California. The term "source segregation" as used herein refers to both separation of refuse by the generator and separate collection of the different waste streams by specified collectors. The four-month experiment, performed from August 1 through November 30, 1976, called for basewide (tenant activities included) voluntary separation of solid waste into nominally combustible and noncombustible fractions. The combustible fraction was limited to paper, plastic, and cardboard; all other materials were defined as the noncombustible fraction.

The source segregation experiment constituted a major element of Project TRASH, a concept for an innovative approach to resource recovery. It combines two-category source separation with mechanical processing to improve the cost effectiveness of resource recovery. A comprehensive report on Project TRASH is contained in Reference 1. This reference also describes the projects role in this overall Navy RDT&E Solid Waste Program.

The experiment was designed to resolve questions about the workability of source segregation and to provide a quantitative basis for evaluation of the cost effectiveness of source segregation at Navy Shore installations.

The experiment was designed by CEL. Prior to implementation, CEL contracted with SCS Engineers (SCS), Long Beach California, to gather data on the effectiveness and cost impact of source segregation during the course of the experiment. Also prior to implementation, CEL contracted with Community Relations Services of Camarillo, California to design, conduct and evaluate a human factors survey of the base population before the start of the experiment. This contractor was then utilized after completion of the experiment to conduct a similar survey.

BACKGROUND

Refuse generated in the Navy shore establishment is generally about 70 to 90 percent (by volume) combustible[1]. For that reason, it is highly desirable to use the waste as an energy source, thereby conserving fuels which have become less available and more costly.

One approach which has been used to prepare the waste as a fuel is to process it through a shredder, and then separate the noncombustibles, with additional equipment, prior to burning. However, this requires a large capital investment in the processing equipment, which in turn requires excessive power[2] because it must be capable of handling metal objects contained in the refuse.

Another approach is to burn the total solid waste stream and then recover the recyclable materials from the ash. This approach demands a larger incinerator, which adds to the capital and operating cost of the processing facility. However, the primary disadvantage of this method can be the hazard risk since the solid waste streams can include toxic and volatile materials; these could cause great harm to the incinerator operators and other personnel located close to the incinerator, as well as add pollutants unnecessarily to the air. Heat recovery efficiency is lower if a mixed stream is burned because the noncombustibles absorb considerable energy. Also, metal objects often interfere with the ash removal mechanism in the incinerator.

A reasonably straightforward alternative is to segregate the waste at the source of generation into its combustible and noncombustible fractions. While this kind of segregation would not be expected to provide perfect separation, it would be expected to produce a "combustible" fraction that does not contain large and/or heavy metal objects and which can be processed with much lower expenditure of funds and energy. The fuel would be less likely to contain hazardous items, and some of the noncombustibles segregated at some kinds of sources may have monetary value. Further, new refuse disposal and handling guidelines are being promulgated for Federal Agencies[3]. These standards will require that all Navy activities recover recyclable materials from the solid waste stream. If 70 to 90 percent of the combustible materials are separated from the waste stream at the source, it will significantly reduce the cost and complexity of the equipment required to comply with the new standards.

There has been conjecture regarding the workability and costs of source segregation in the environment of the Navy shore establishment. However, many municipalities formerly required (prior to more stringent air quality regulations) that residents separate their refuse and burn all paper and cardboard, and it appears that little or no enforcement was necessary. The question of workability is clearly addressed by the results of the source segregation experiment described below.

SUMMARY

An experiment was designed, conducted and evaluated to determine the workability and cost of voluntary source segregation of solid waste at a Naval shore activity. Separation was into two categories suitable for resource recovery in an on-base processing plant. The site where the experiment was conducted from 1 August 1976 to 30 November 1976 is the U. S. Naval Construction Battalion Center at Port Hueneme, California. The two waste categories selected were nominally (1) combustible waste, and (2) noncombustible waste.

In the course of design of the experiment, a human factors survey[4] of the site base population was conducted by an outside technical

specialist. This was done to evaluate the CEL approach, recommend means of introducing the project, evaluate attitudes toward the (pending) project, and recommend advertising modes and methods. A public relations campaign was then organized, and the experiment proceeded.

Another contractor was hired to conduct an on-going survey, during the experiment, of the level of effectiveness (participation) associated with the source segregation experiment, and to determine, by survey, the added costs. This contractor's evaluations were based on a pre-test characterization of the base solid waste management system which was also established by his survey efforts. The results of this evaluation[5] show that, given typical Navy solid waste, the purity of the source segregated "combustibles" fraction is sufficiently high (on the order of 90%) for that material to be directly fed to a low cost, reliable refuse-derived-fuel processing line for waste heat recovery (i.e., a line containing no air classifier, and only a flail mill for shredding). The purity of the "source-segregated noncombustibles" fraction was considerably lower (on the order of 60%), and it is expected that the low resale value of these materials would not justify their further processing.[2] The added cost of solid waste management attributable to source segregation was determined to be $1.64 to $2.95 per ton; which is considered to be quite small in light of the potential benefits from waste heat recovery and reduced disposal costs. It is also less than onethird the cost of the required mechanical separation equipment on a per ton basis.[2]

Upon completion of the four-month experiment, a follow-up human factors survey[6] of the base population and the refuse collectors was conducted by the same outside specialist who conducted the preliminary survey. This survey was designed to elicit experiences during the test, determine penetration and acceptability of publicity campaign materials, investigate reactions to an altered pattern of source segregation, and elicit suggestions for improvement in methods.

DISCUSSION

OBJECTIVE

The objective of the experiment was to quantify the effectiveness and cost factors associated with source segregation of refuse into combustible and noncombustible fractions at Navy shore activities. For this experiment, the combustible fraction was defined as paper, plastic, and cardboard, while all other materials comprised the "noncombustible" fraction. Wood was not included in the combustible fraction because compactor trucks are used to collect the combustibles and wood tends to wedge into the compactor mechanism.* The experiment

*NCBC requested that wood not be collected with compactor trucks because it wedges into the compactor mechanism.

concentrated on means of source segregation which can be implemented with minimum capital investment. Emphasis was on quantification of (1) segregation effectiveness (i.e., percent of segregation at each source type), (2) estimated percentage increase in operating costs attributable to source segregation for each source type, and (3) estimated additional equipment requirements and investment, on a unit basis, at each kind of source.

PLANNING AND IMPLEMENTATION

The experiment was conducted on a scale large enough to resolve questions of workability and provide a quantitative basis for evaluation of the merit of source segregation in the Navy shore establishment. The approach taken was to conduct a base-wide experiment on source segregation of solid waste into combustibles and noncombustibles at the Naval Construction Battalion Center (NCBC), Port Hueneme, California. This Navy base encompasses a variety of activities and work areas, including offices, warehouses, receiving and shipping areas, construction training areas, shops, and deep-water ship docks. In addition to these, there are facilities such as mess halls, cafeterias, automobile service stations, commissary, Navy Exchange stores, barracks, and residences which serve the 10,000 people working and/or living on the base--civilian employees and military personnel and their dependents, all of whom discard refuse daily.

Following the initial development of the concept, the objectives, and the scope of the experiment, there were several stages in the advance planning and preparations. These were accomplished, as follows:

1. Steps were taken to secure the approval and support of the administration of the activity selected for the experiment (NCBC, Port Hueneme) and the cooperation of Public Works/Transportation personnel at that activity. Care was taken that the experiment would be conducted with a minimum of interference with normal refuse pickup operations.

2. A survey of the entire base was conducted to determine the characteristics of each refuse source and the nature and quantities of refuse produced. Procedures and equipment requirements for segregation at each source were developed. To accomplish this, a CEL engineer personally monitored pre-test refuse collection operations, riding for one week with each of the three collection trucks involved. The locations of all existing outdoor refuse containers were marked on a map of the base, and notations were made to show where refuse containers must be added or relocated to implement the source segregation experiment. These map markings were coded to indicate locations of containers by type--compactible

(combustible) and noncompactible (generally noncombustible). Figure 1 shows a typical section of the marked base map. Basically, there were a minimum of two containers at each disposal location, one for each category. (For additional information, see Appendix A.)

The additional containers required for the experiment were obtained from three sources: (a) some were determined to be on hand as spares, needing only some repair and painting, (b) about 40 were found as excess at Pacific Missile Test Center and were transferred to NCBC, and (c) a group of 50 containers being reconditioned for shipment to another base was acquired on loan for the duration of the experiment from the Civil Engineer Support Office, NCBC. Containers from all three groups were reconditioned as necessary. A relocation/placement list was prepared and used as a guide in deploying the containers as required.

3. A telephone survey of six representative Navy shore facilities was conducted to determine: (1) what procedures and communications media are typically used at Navy facilities to convey information to all military personnel on base, their dependents if living on base, and civilian employees, (2) who or what office takes action to direct a change such as source segregation, and what action they would take, and (3) what follow-up-monitoring is typically done to reinforce the initial implementation and to reinforce compliance. The results of this survey indicate that no standard Navy procedures exist. The only releases found consistent in the survey are the release of instructions or directives (which are required), and base newspaper releases.

4. Human factors consultants were employed[4] to interview key people in base housing, public works, and public affairs in regard to drives, energy conservation, and community structures. Subsequently, they made a public relations survey of a selected sample of the resident population of NCBC housing and evaluated the program to examine the human factors involved in the design and implementation of the experiment. The results were analyzed and used to: (a) recommend the most effective shape, size, format, and coloring of segregation instruction labels to be affixed to the containers, for quick user comprehension, (b) recommend the most effective public relations effort that would be within Navy standard procedures, and (c) validate the approach of the fourmonth experiment. Their results, conclusions, and recommendations[4] are summarized in the next section. The resulting designs for labels are illustrated in Figure 2.

5. Results of the survey of Navy bases and the human factors survey were analyzed and a plan was developed for the public relations (PR) campaign to announce, initiate, promote, and support to conclusion the four-month experiment at NCBC. The PR campaign is described later in this report.

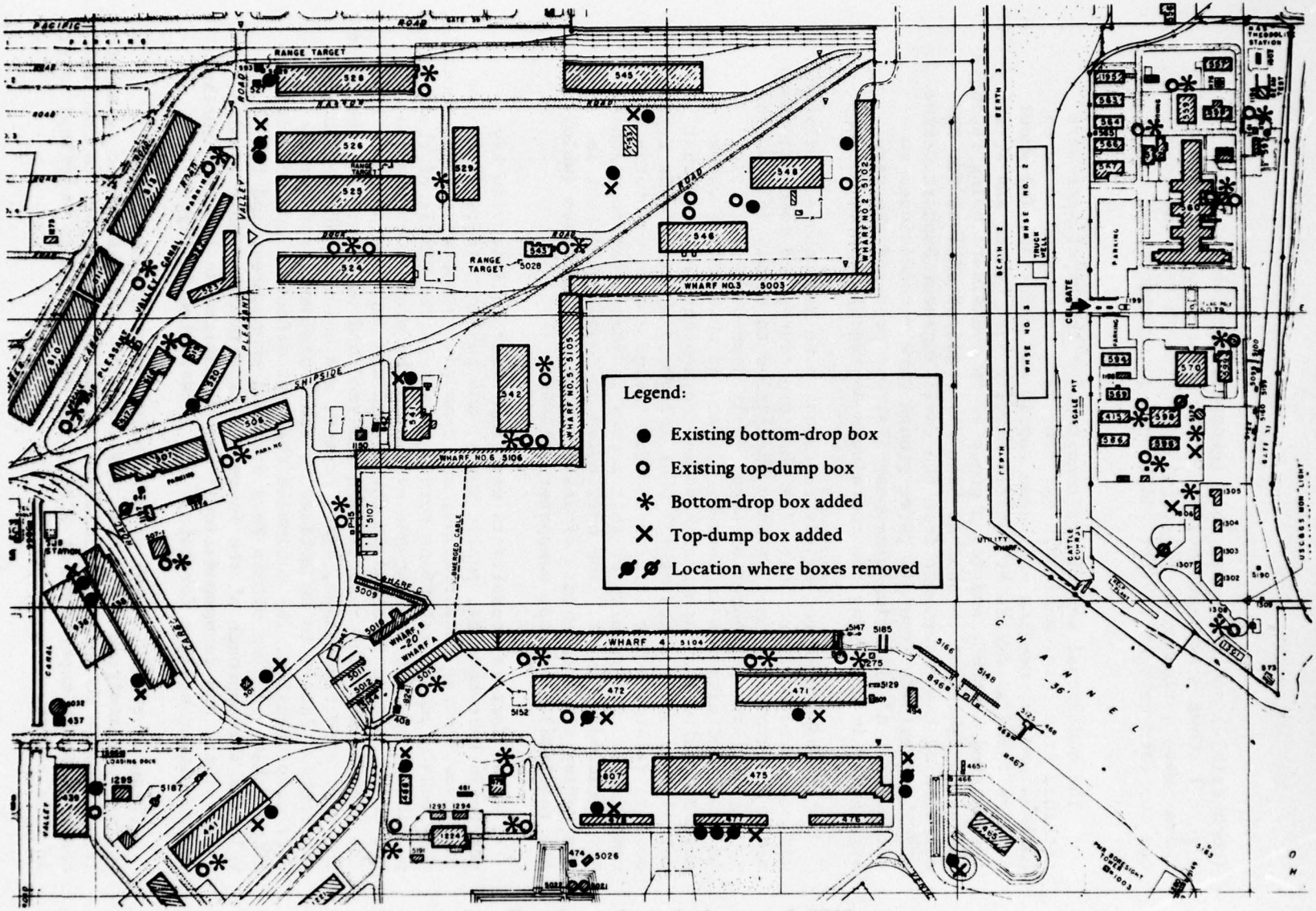

Figure 1. Section of marked map of NCBC.

Figure 2. Labeled residential trash containers.

6. A contract was awarded for the measurement of the degree of segregation achieved and for the determination of any additional costs incurred in gathering and collecting the segregated refuse over the four-month period of the experiment. The details of the work performed under the segregation evaluation contract are outlined in Appendix B.

PRELIMINARY HUMAN FACTORS SURVEY

The report on the human factors survey[4] validates the approach taken in the experiment, and recommends means of introducing the experiment to the target population. It presents characteristics of the target population with respect to the solid waste source segregation concept, current solid waste collection behavior, media utilization, motivational factors, and response to suggested advertising and labels. The report indicated that the people interviewed were first given the following brief explanation:

> "In a month or so, a program will be tested at CBC. This program will involve the separation of trash into burnable materials and nonburnable materials. The materials which can be burned are paper, cardboard, and plastic. All households, shops, and offices in CBC are being asked to participate in this test. In the housing area, additional containers will be placed outside of the house in conventional locations, clearly marked as to contents. The test is planned to last for four months. The goal of the program is to collect the burnable trash and use it as fuel to generate steam."

Then they were asked: "Would you tell us what you think about this plan?" The report stated that, with few exceptions, the initial response to a description of the project was positive. Readiness to participate and a desire to be involved in recycling were expressed. The idea of producing energy was well received. "If it helps" was frequently expressed. There followed questions about their trash disposal patterns and their previous experience with trash segregation or separation of recyclable materials. It was found that a significant number of respondents had been involved in some sort of recycling effort and that a few were presently participating. Subsequent questions covered their "media readership" with reference to Navy and local community publications. Some preference was found for the Oxnard Press Courier, and there was interest in the advertisements in the Harbor News; both are local newspapers. The most widely read base publication was the Hospital

Bulletin, with the Recreation Bulletin placing next. Specific percentages were found to be as follows:

74% read Press Courier	82% read Hospital Bulletin
46% read Harbor News	70% read Recreation Bulletin
36% read Navy Times	62% read Housing Bulletin
16% read Los Angeles Times	46% read Coverall

In addition to these, the claim was made that 100% of the husbands read the official "Plan of the Day."

The survey explored the response to posters, to labels to be used to identify container contents, and to various motivational approaches. Many seemed to view the goal of the program as its own reward. The final question asked if there were anything that would make it difficult to separate their trash. Complaints about lack of space were not related to size of quarters. Almost universal dissatisfaction with dumpsters was expressed; in some cases the addition of a second dumpster was seen as an ameliorating factor. The fact that young children (one aged 3) dispose of trash was also cause for concern. "Parents will have to teach their kids." The attitude, "It may be hard in the beginning, but we'll get used to it", was widespread.

Several conclusions were drawn in the report, as summarized in the following.

Validity of Experiment

Review of studies indicates that the planned three-month duration of the test monitored by the contractor (SCS Engineers) is sufficient to determine realistically the level of compliance which can be expected from the target population; the test will measure the readiness of the population to support the planned source segregation project. The last month not mentioned by the contractor will be spot checked by CEL to verify contractor results.

Container Labels

The labels submitted for survey purposes were examined with respect to contract, content, letter size, stroke-width-to-height ratio, letter width-to-height ratio, and letter style. Legibility and communication criteria appear to be met by these labels.

Means of Introducing Experiment

a. Clear, explicit instructions are critically necessary in order to make compliance possible. A compliance-defeating credibility gap occurs when confusing, contradictory information is disseminated, or when information is withheld.

b. Coordinated campaigns achieve higher compliance than random efforts. Such campaigns include the planned release of a variety of materials through diverse channels, the released materials having consistent message, color, themes, and format.

c. A higher allocation of resources to the initial persuasive effort usually results in a higher level of compliance.

d. Involvement of the school, community, and media components in a campaign achieves higher compliance.

Motivation

a. Base personnel are diverse in nationality, attitudes and allegiances.

b. Using a complex message limits the effectiveness of any introductory effort.

c. The feeling of being "special" because they were chosen for the test (the Hawthorne effect)[4] is an effective motivation.

d. There has been extensive exposure of base personnel to drives (such as Combined Federal Campaign, and Operation Clean Sweep).[4]

Reinforcements

a. Without post-introductory reinforcement, the initial compliance tends to decay (i.e., be extinguished).

b. Once habits of compliance or non-compliance are established, resistance to change may necessitate extensive effort if compliance is to be increased.

c. Altering anything that relates directly to the compliance habit (such as pickup schedules, or numbers or locations of containers) reduces likelihood of compliance. The continuation of such factors without change is one of the most powerful reinforcements.

d. Where possible, positive reinforcements are preferable to negative reinforcements. Negative reinforcements may be effective, but tend to have side effects which cannot always be anticipated.

e. Intermittancy of reinforcement is more important that intensity of reinforcement, in achieving compliance.

f. Ongoing feedback of project accomplishment to participants is necessary to obtain continued compliance.

g. It is necessary to have a channel for information to flow from participants to project administration, in order

to minimize problem buildup and to uncover compliance-reducing factors before they have significant effect.

h. There appears to be a positive correlation between economic level and degree of compliance. The applicability of this trend to a military population is unknown.

Agents

a. The use of agents is usually a very cost-effective tactic in changing behavior. (Agents are defined as individuals or groups of individuals who are directly involved in working for the success of the project.)

b. The commitment of agents is heightened when they are involved in the decision-making process.

c. The use of the base housing office as an agent is advisable for indoctrination of new residents. Materials should be prepared for distribution through Base Housing to all newly arrived base residents.

PUBLIC RELATIONS CAMPAIGN

The public relations (PR) effort for the solid waste source segregation experiment closely followed the suggested news media and procedures derived from the human factors survey, shown in Table 1. The underlying philosophy of the PR effort was that all releases were aimed toward informing the receivers of what is requested of them and why through clear instructions and explanations, without providing intentional motivation. The more informative releases (i.e., longer articles) clearly pointed out that no single person, group, or activity was to be warned, penalized, or even documented for non-compliance.

The Public Affairs Office at CEL assigned a PR specialist, part-time, to work with the project engineer on the four-month experiment. His assignment was to instruct, not persuade, the 10,000 military and civilian employees and residents at CBC how to volunteer their efforts. Since participation was totally voluntary, it was vital to get the word out early and often through every conceivable means of communications. Because most PR techniques use various news releases and because "old news" is "no news", a high intensity introduction was important. It also was necessary to sustain an atmosphere of interest during the test. The campaign was implemented with all releases having a consistent message, color, theme and format and being distributed through a variety of diverse channels. The publicity package was designed to encourage an attitude of cooperation wherein each volunteer felt that his/her contribution would be the key action towards success.

TABLE 1

NCBC PUBLIC RELATIONS CAMPAIGN FOR SOURCE SEGREGATION EXPERIMENT

ADVANCE PUBLICITY

1. Feature coverage in Coverall (base newspaper).

2. Feature coverage in Press Courier (local newspaper).

3. Feature coverage in Harbor News (local newspaper).

4. Announcements in Housing Bulletin.

5. Announcements in Hospital Bulletin.

6. Announcements in Recreation Bulletin.

7. Flyers/handbills to everyone (hand out at gate or door hangers).

8. Notice in Plan of the Day.

9. Notice in Plan of the Week (CEL).

10. Announced/discussed in staff meetings and passed on through departments and divisions.

11. Posters on all bulletin boards and other "high visibility" locations.

12. Local radio stations.

SUSTAINING/FOLLOW-UP PUBLICITY

1. "Progress" articles in Coverall.

2. Progress/reminders in Housing Bulletin.

3. Progress/reminders flyers/handbills at midpoint (2 months).

4. Change reminder posters every 4 weeks.

5. Photo reproduction of posters (on base theatre screen).

6. Feedback channel from participants to CEL. Phone number, day/night (answering service for nights and weekends).

The Public Affairs person relied solely upon typical tools of his trade, normal day-to-day methods and procedures, to explain the project and define its goals. Extraordinary means of publicity and promotion, geared toward influence and persuasion of potential volunteers, were not used.

Facts and figures were released in the conventional publicity program (i.e., segregation purity as a function of source type, etc.), with the realization that such information, once disseminated and studied, might instill self-motivation among personnel and prompt them to volunteer.

Publicity for the source segregation experiment was planned three months prior to start-up. The human factors study of the base population served as a basic guide.

Once the project received initial exposure, the experiment was kept before the public's eye through regular articles placed in the base newspaper, repeated announcements in various in-house publications, and reminders in different bulletins.

The Commanding Officer of NCBC was featured in a two-minute film wherein he championed the cause and encouraged personnel to separate their trash into two categories. The film, in color and with sound, was screened nightly at the base theatre.

A number of individual meetings of CEL project leaders with NCBC officers, division/department leaders and other administrators were held. Detailed plans were discussed and evaluated, and timetables of action were coordinated. Maximum cooperation was assured weeks before the project started because frequent communications at all levels were commonplace. These communications set the stage for public exposure. The methods of communication used are described below.

Newspapers (military)

a. The Seabee Coverall, which is the base newspaper, was most instrumental in telling the story. A cover article preceded the test. During the experiment, every edition of this bi-monthly newspaper featured a progress report prominently displayed as a major "local" news story. Photographs and cartoons were frequently used to pictorially add impact to the printed word.

b. The CEL house publication regularly carried articles and photographs. No requests for space were refused.

c. The Naval Ship Weapon Systems Engineering Station (NSWSES), a tenant activity with some 3,000 employees, published several major articles in its newspaper.

Newspapers (civilian)

a. Prior to the actual experiment, the project received major favorable publicity from Ventura County's largest daily newspaper, the Star Free Press, which has a circulation of 35,000. The paper's military reporter met with CEL project leaders, the authors of the human factors study, and Public Affairs representative. The result was an excellent early article leading into the project.

b. Other Ventura County daily newspapers - - Oxnard Press Courier, Santa Paula Chronicle and Camarillo Daily News - - provided excellent coverage of the Navy's unique source separation test. Each paper averaged three stories.

c. At least six county and area weekly newspapers also published prepared news releases.

Posters

The successful placement of two-color posters in practically every advantageous area of the base was the result of direct contact with persons in charge, followed by personal delivery of a predetermined number of posters.

Posters were designed and drawn by the Presentations Division at CEL. A total of 24 large (3 ft by 4 ft) posters were prominently displayed at all base entrances, at the base theatre, and at other points of high visibility. A vast majority of 3,000 smaller (11 in by 17 in) posters were distributed as follows:

a. Office Services Division - - Volunteered to deliver 400 posters via an all-encompassing distribution list.

b. Navy Exchange Office - - agreed to display 50 posters on food distribution vehicles, at canteens, and at other facilities.

c. Special Services - - Requested 200 posters for display at the skating rink, golf course, swimming pool, arts and crafts building, gymnasium, bowling center and various bulletin boards.

d. Safety Directory - -Granted permission to use the seven extra large billboards located within the base complex.

e. Public Works Officer and Transportation Director - - Granted permission to place 300 posters on Navy vehicles. Public Works personnel placed the posters.

f. Posters were also displayed at the base Community Center, Housing Referral, bank, post office, hospital, barracks and mess.

Radio Coverage

a. News stories and interviews aired on three local radio stations.

b. A four-minute news report was broadcast on "Navy Scene", part of Armed Forces Radio Network and heard around the world. Millions of listeners became aware of the Navy effort in energy conservation and environmental protection.

c. Upon request, public address systems were used. For example, at CEL, announcements were made several times a day during the development stages of the project.

Other Means of Communications

a. The CBC Plan of the Day, CEL Plan of the Week, Base Housing Bulletin, Hospital Bulletin, and Community Center Bulletin were all used to publicize the project.

b. Through the Navy Civil Engineer magazine, Navywide and international exposure was gained through a major story in the Summer 1977 edition. The magazine is the official publication of the Naval Facilities Engineering Command (NAVFACENGCOM) and is widely read throughout the Naval community.

PRE-TEST CHARACTERIZATION OF BASE

A characterization of solid waste management at NCBC Port Hueneme was performed during July 1976, one month before the start of the test. These pre-test data were used as a basis for evaluating source separation effectiveness and cost impact of the program. Aspects of NCBC waste management which were analyzed included solid waste composition (combustible and noncombustible fractions), various on-base waste collection activities, and waste disposal operations.

For the purposes of this experiment, a system of categorizing solid waste sources at NCBC was developed. The seven source categories are listed in Appendix B. These categories were used (1) to identify differences in collection operations, such as custodian collection, and (2) to evaluate program performance by source type.

Furthermore, the various refuse containers on base were categorized according to size and location. The five container categories are also listed in Appendix B.

These categories, coupled with source types, were used to isolate areas of strong compliance and non-compliance at the base.

Solid Waste Composition

The solid waste generated from source categories A-G at NCBC was analyzed to determine its composition. The sampling period extended from 12 to 14 July 1976. The composition categories consisted only of

combustible and noncombustible materials. The term "combustible" referred only to paper, cardboard, and plastic-like material. Combustible materials other than paper, cardboard, and plastic (e.g., wool and rubber) were excluded intentionally from the "combustible" category.

As a necessary prerequisite to the actual sampling procedure, a matrix of source categories and their associated container types was developed. Based on this matrix, a sampling schedule was developed to provide both sample container locations and the minimum number of samples for each category.

The sampling matrix and the results of the sampling procedure are shown in Table 2. The number of sorts far exceeded the number planned, providing 260 composition data points from visual sampling and 26 from manual sorting.

The manual sorting procedure minimized the disturbance of normal collection operations. Instead of working inside the trucks, selected Type IV containers were emptied into one of the front-end loader vehicles and transported to the sampling team at the stationary compactor site on base. There, the crew spread and sorted the refuse and subsequently shoveled the material into the stationary compactor. This permitted a view of the contents of several bins from one source, while the truck proceeded to pick up several more bins fron another source type. The entire sort procedure (14 bins in all) took less than six hours to perform.

The manual and visual sorts were supplemented with photographic sorts, as suggested by the NAVFAC R 4 Decision Guide.[7] The "photosort" results (not reported here) were used as an informal check on the accuracy of the sampling team's results, although no adjustments were made in the data.

Solid Waste Collection Operations

The pre-test NCBC solid waste collection system was surveyed during the period of 12 to 14 July 1976. Time studies of the following collection subsystems were performed:

a. Custodial collection in the various office and warehouse areas.

b. Navy collection of solid waste from base operations.

c. Contract collection of solid waste from the base housing areas.

As the mechanics of each operation are different, the time studies were tailored to the particular subsystems. The results for each subsystem are described in the following.

TABLE 2

COMPOSITION ESTIMATES (BY VOLUME) FOR VARIOUS SOURCE AND CONTAINER CATEGORY COMBINATIONS
NCBC PORT HUENEME
(combustibles)

Container Classification[a]	Source Category[a] [b] A		B		C		D		E		F		G		Total No. of Sorts
	No. of Sorts	% Comb.	No. of Sorts	% Comb.	No. of Sorts	% Comb.	No. of Sorts	% Comb.	No. of Sorts	% Comb.	No. of Sorts	% Comb.	No. of Sorts	% Comb.	
I	25	90	8	81	14	75	1	95	--	--	6	83	--	--	54
II	2	52	6	78	7	49[c]	15	46	--	--	27	76	16	51	73
III	--	--	--	--	--	--	--	--	46	70	--	--	--	--	46
IV	11	89	22	78	7	63	10	66	--	--	21	80	16	77	87
Total No. of Sorts	38		36		28		26		46		54		32		260
Manual Sort Data	3	98	2	75	3	54	2	92[d]	12	84[e]	2	60	2	70	26

Note:

a. See Appendix B for source categories and container classifications
b. Yard wastes included as non-combustibles (15% by volume on Monday)
c. Much mechanical repair waste disposed of in exterior containers
d. Predominantly corrugated boxes
e. Yard wastes excluded in composition analysis

Custodial Collection

Custodial operations at NCBC are limited to office buildings and certain office-warehouse complexes. These operations are performed by a contractor, Geronimo Janitorial Service, at a cost to the Navy of $860,000 per year. Collection equipment for the custodians is supplied by the Navy.

Evaluation of the custodial operations required that a time study be performed for selected tasks. Inherent differences between office functions from one building to the next make it difficult to define a common unit operation for custodial time studies (e.g., time per can, time per floor, etc.). It was, therefore, decided to select several office buildings and analyze the same custodial operations before and after program implementation.

Four representative office buildings were selected for pre-test sutdies. These buildings were:

Building No.	Description
363	Administration/Computer Facility
442	Administration Building
452	Administration Office
850	Public Works Administration

For each building, pre-test time study elements included collection time (travel time between cans plus can dump time), travel time to and from Type IV containers, dump time at Type IV containers, and any delay or break times. The number of Type I containers was also recorded, as was the number of rooms serviced where applicable.

The results of the initial custodial time study are presented in Table 3.

Table 3. Results of Custodial Time Study

(All times in minutes)

Bldg. No.	No. of Cans	No. of Rooms	Average Pickup Time Can	Average Pickup Time Room	Haul Time	Average Pickup/Haul Time per Can
363	21	11	0.66	1.17	1.56	0.72
442	66	28	0.47	1.10	3.76	0.53
452	78	21	0.40	0.93	1.53	0.42
850	60	29	0.44	0.91	3.63	0.50

The spread in average times for each unit operation (0.42 - 0.72 minutes/can total and 0.40-0.66 minutes/can pickup) verifies the presupposed need to limit comparisons to within buildings and not between buildings.

Qualitative studies of several other custodians were performed to determine if rate adjustments were necessary for the time study subjects. Adjustments of this type are often necessary, as performance of the participants can be affected by study conditions. It was determined, however, that no adjustments would be necessary in the pre-test custodial collection data based on these observations.

Navy (Truck) Collection

The Collection of solid waste from the non-residential areas of NCBC is performed by civilian drivers using Navy collection vehicles. Collection vehicles include two front-end loaders and one hoist-and-haul vehicle.

The NCBC Transportation Department operates two PakMor front-end loading compactor vehicles with capacities of 24 cubic yards and 32 cubic yards, respectively. Each operator has assigned routes, yet maintains sufficient flexibility in his route to respond to calls.

Time studies of the front-end loader operations were performed during 12 and 13 July 1976. The results of the study are presented in Table 4. Each of the individual time studies involved a different set of time-study elements, with only the total cycle time being important to program evaluation. The elements were defined as follows:

Load - Time required to check inside bins; close bin doors; and engage, dump, shake, reset, and disengage bins (and sometimes to compact the load).

Maneuver - Time required to disengage one bin and maneuver to engage an adjacent bin.

Travel - Driving time between bins.

Pack - Time required to compact load before dumping next bin (usually done while driving with the 32 cubic-yard front-end loader).

Set-Up Time - required to engage bin and check inside for children, etc. (was considered part of both load and maneuver time in initial studies).

While the definition of travel time remained constant, set-up and maneuver times were later combined (see Table 4). In addition, the 24

TABLE 4. SUMMARY OF PRE-TEST TIME STUDY RESULTS - ALL VEHICLES

Vehicle (a)	Time Study Elements (minutes) Load[f]	Maneuver[f]	Travel	Pack[f]	Set-Up	No. of Cycles	Total Cycle Time[b]
Front End Loader #1	1.47	0.50	1.67	1.04	1.51	18	4.70
Front End Loader #2	0.77	(c)	1.32	0.86	1.47	26	3.75
Front End Loader #1[d]	1.65	0.41	1.24	(c)	(d)	20	3.74

	Hoist Bin	Haul Bin	Dump Bin	Compact[f] (Stationary Compactor)	Return Bin	Drop Bin	To Next Bin	Total Cycle Time[b]
Hoist and Haul	1.38	7.31	1.33	2.57	5.74	2.19	2.17	(e)

Notes:

a. Front End Loader #1: 32 cu yd Pak Mor, Front End Loader #2: 24 cu yd Pak mor
b. + Average of all cycles, in minutes
c. Included in travel time
d. Set-Up time is included in maneuver time.
e. With compaction: 23.0 minutes, without compaction: 18.07 minutes, wet garbage: 18.0 minutes
f. Average of finite-valued time study elements only (i.e. does not include cycles where element was not performed).

cubic yard vehicle could not compact while moving and, therefore, required an additional time study element (Pack Time). The 32 cubic yard vehicle was compacted while stationary on several occasions, but not by necessity.

The NCBC collection system includes one hoist-and-haul type of vehicle. The collection route includes a few scheduled stops, although most of the remaining stops are selected based on operator experience. Under ordinary circumstances, this vehicle would drive to the location of a full bin, hoist and haul the bin to a stationary compactor, dump the bin, and return the bin to its proper location. The source segregation program included use of the hoist-and-haul bins solely for noncombustible materials. Only the contents of these bins was to change as a result of the program, and not the bins themselves. The program was expected to have little effect upon the productivity of or the demand for hoist-and-haul collection due to a reduced loading rate per can. Nonetheless, a time study was performed on the hoist-and-haul collection operation. The results of the one-day study are also shown in Table 4. The following is a list of definitions of the time-study elements used:

Hoist Bin - Time to engage and pick up bin.

Haul Bin - Travel time from bin location to stationary compactor.

Dump Bin. - Time to empty bin into stationary compactor.

Compact - Time to operate stationary compactor.

Return Bin - Time to return bin to original location.

Drop Bin - Time to drop and disengage bin.

To Next Bin - Time running empty between bins.

Total Cycle Time - Elapsed time from one operation on one bin to the same operation on the next bin.

The average total cycle time was 18.0 minutes, not including compaction with cycles ranging from 14.5 minutes to 29.0 minutes. Part of the reason for this wide range is that the driver would not compact the stationary compactor during every cycle.

Residential Collection

The collection of solid waste from residences at NCBC is performed by a contractor. The collection vehicle is a 30 cubic yard front-end loader with a two-man crew.

There are three residential sectors at NCBC: officers' housing, chiefs' housing, and enlisted men's family housing. Collection in the

officers' and chiefs' sections is curbside, predominantly from 30-gal cans. The crew empties the cans into a 3 cubic yard bin carried on the loading forks of the vehicle. When filled, the bin is emptied into the vehicle. Collection is performed three times per week (Monday, Wednesday, and Saturday). Area locations are shown on Figure 3.

The enlisted men's family housing area, known as Bruns Park, is also serviced three times per week. Each housing unit houses from two to six families. Each housing unit or pair of units is supplied with several blue 3 cubic yard bins. These "blue bins" are routinely collected, and there was substantial excess bin capacity observed at most locations for three-times-per-week collection. The results from the pre-test study are presented later in this report in Table 9.

Disposal

With the exception of some wet garbage and recycled materials, all solid wastes generated at NCBC are disposed at the Ventura County Landfill. The landfill has an expected useful life in excess of 10 years. The current disposal fee is $2.00/ton, with weights determined by a scale at the landfill.

Residential refuse is delivered to the landfill by the contractor. The dumping fee is included in the contract cost. The collection vehicle is rarely if ever filled when it leaves the base, and often makes several collection stops outside the base on the way to the landfill. Weight data were not available from the contractor, and probably could not be translated to Navy waste due to the stops outside the base.

The daily weights of refuse delivered to the landfill by Navy vehicles were tabulated[5]. The average daily weight during the month of July was 15.12 tons/day on a seven-day basis, excluding residential waste. The residential waste generation rate was an estimated 4.12 tons per day on a seven-day basis.

PROGRAM EVALUATION

The ultimate measure of the success of a source segregation program is its ability to recover and exceed the incremental cost of separate collection and program administration through materials and/or energy recovery revenues. The objectives of this study were (1) to assess the incremental costs of separate collection, and (2) to monitor the quality of the segregated product.

Problem Areas

Source separation/separate collection programs involve more than a program design and publicity campaign. The start-up phase of such a program involves a "fine tuning" stage in order to correct unforeseen problems. The following is a discussion of problems reported during the program.

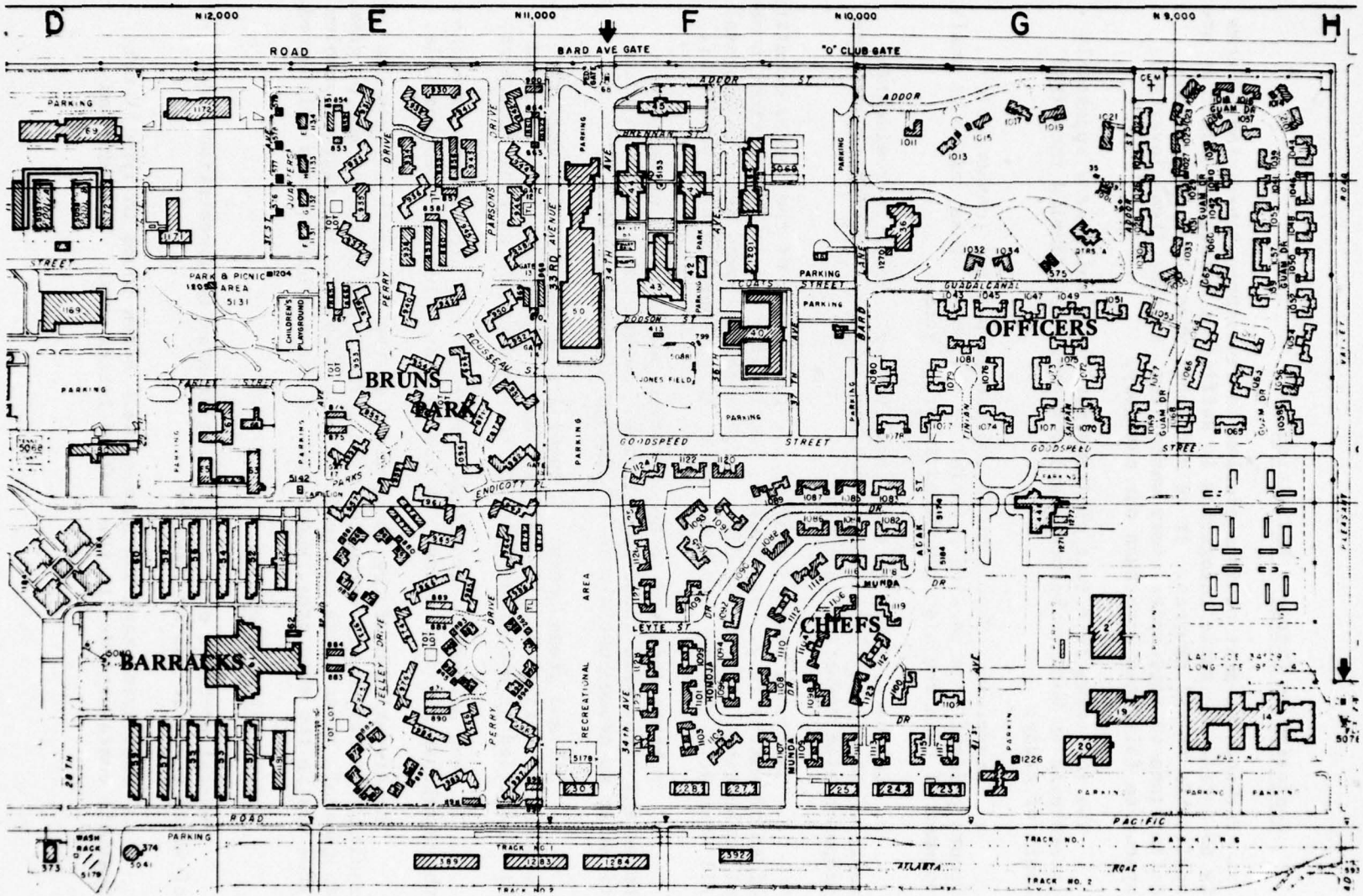

Figure 3. Area locations.

Confusion in Category Definition

Perhaps the most obvious problem in any source separation program is to define the waste categories in sufficient detail so that they are applicable to all sources. It is difficult when formulating these definitions to anticipate every waste item, so some items invariably appear to fall into more than one category.

The following is a list of items/materials which were apparently interpreted as both combustible and noncombustible during the first month of study:

a. Styrofoam: Should be classified as plastic (combustible). Occurs primarily as packing material in warehouse areas, although small volumes of cups are also generated in other areas.

b. Leather: Shows up occasionally (e.g., shoes in residential waste). Should be classified as noncombustible in accordance with the proposed size reduction equipment.

c. Cardboard boxes: Many of the generators of the larger quantities of solid wastes (e.g., warehouses, commissary) had an insufficient number of combustible bins and/or did not collapse the boxes prior to disposal. All bins were used for cardboard once the appropriate bins were full.

d. Rubber: Appeared to be a problem only in shop areas, where hoses and tires were found in all bins. Rubber was classified intentionally as noncombustible in the design of the experiment.

e. Oil and grease cans: A special problem, as these cans are composed of cardboard cylinders with metal tops and bottoms. Should be classified as noncombustible due to shredder design considerations.

f. Wood pallets: Several were found in and around bins throughout the warehouse and dock areas. Should be classified as noncombustible.

The disposition of the above items in the two waste streams was monitored continuously throughout the first three months of the program. In general, these items continued to be a problem. The biggest problem area was in the shop area, where most of the confusing items originated.

Implementation Problems

Several problems developed during program implementation, most of which could be easily remedied.

a. Soft drink cans and bottles were often found in Type IV combustible containers due to the lack of litter cans. The same was

true for Type I cans around vending machine areas, but to a lesser extent.

b. Many of the "blue bins" in the Bruns Park area showed no signs of any separation on the part of residents. While this might have been expected, it was also noted that the gardeners who cut the lawns in this area deposited the grass clippings in the nearest bin. In several instances, grass filled bins for both noncombustible and combustible materials.

c. The problem with the ID stickers on the various bins included fading beyond recognition, peeling off with or without help, and the placing of more than one type of sticker on the same can. These problems were pinpointed and corrected during the program. New sunlight-resistant labels were placed on all the outdoor containers within the first month of the experiment.

d. Many of the offices (particularly secretarial pools) had an insufficient number of noncombustible Type I cans. Some secretaries removed staples and paper clips from all paper, but had no accessible place to dispose of the metal. Several individuals labeled cardboard boxes for this purpose, but wet garbage from lunch caused the unlined boxes to leak and deteriorate.

e. Source B containers, although generally fairly pure in content, were prone to unusual violations which could cause problems during processing. Examples of such contaminants included metal hinges, pallets, large and small cans, and a variety of glass items.

f. In contrast to the lack of compliance in Bruns Park (enlisted men's housing), most of officers' housing generated a fairly clean stream of bottles and cans in the noncombustible 30-gallon cans. Most of the wet garbage and borderline items, therefore, went into the combustible stream.

Analysis of these same problem areas during September found that many had been corrected, either intentionally or by evolution of the program. In particular:

a. Soft drink cans and bottles were still frequently found in Type IV combustible material containers due to the lack of litter cans in some areas. This confusion was cleared up in the vending machine areas, and the associated waste streams were often noted as being 100 percent pure.

b. The "blue bins" in Bruns Park remained a problem area in the program. Grass clippings were still indiscriminately deposited in both types of bins, sometimes filling them to capacity. Combustible purity appeared to have stabilized at about 75 percent for the Bruns Park area, including yard wastes.

c. The stickers on some "blue bins" were apparently replaced. However, some bins had two conflicting stickers, while other stickers were obscured from view.

d. The lack of cans for noncombustibles in certain office areas appeared to have been rectified in some cases. A common complaint at the September site visit was that only combustible cans were in certain office complexes, and employees often had to cross a hall to dispose of noncombustible refuse.

Similar analysis during October and November indicated no further problems in program implementation.

Collection Problems

At the outset of the source separation experiment, both the janitors and the residential collection contractor showed an inclination to dump the contents of both combustible and noncombustible bins together into the same container. This action prompted many people to simply disregard the program instructions or call various base offices to complain. The contractor was subsequently required to make separate collection runs. It is noted, however, that contractor collection of residential refuse remained a problem throughout the duration of the test inasmuch as he continued to mix refuse categories in plain view of residents. The problem was never alleviated. A CEL engineer monitored the residential collection when time permitted throughout the length of the experiment.

Problems with the janitorial service were not as clearcut. First, many of the janitors empty the waste baskets after close of business and are therefore not subject to employee scrutiny. During the test, it was not uncommon for a janitor to combine the two waste types in his roll-away container. Second, some janitors must cover an extensive office area in their allotted shift and could not complete two runs in the allotted time.

While many custodians combined waste streams, others devised methods of collecting both streams separately in one run. These included the collection of noncombustible waste in liner bags and in side bags supplied by the contractor to store noncombustibles separately from combustibles.

Program Effectiveness

The typical method of assessing separation effectiveness is simply to monitor revenues from the sale of recycled materials. At NCBC, the lack of an ultimate buyer for the segregated waste required that other intermediate measures of program success be employed. These included (1) measuring the purity of segregated waste, and (2) computing the effectiveness of separation at each source, based on the measured purity.

Collection of Purity Data

The composition of each separated waste stream was determined approximately biweekly throughout the duration of the program.

Contractor field technicians employed several sampling techniques, including visual estimation, hand sorting into components, and photographic sorting of the waste streams. Visual estimates were performed for the smaller containers, and manual sorts were performed for the refuse trucks in the vacant area adjacent to the stationary compactor. Photographs of the waste were taken at both locations. The results were then combined and reported monthly. Table 5 summarizes the sorting schedule for the four months.

The parameter used to monitor segregation was "purity". Purity of combustible (P_c) and noncombustible (P_n) wastes were defined as the percentage by volume of material belonging to the indicated separation category (i.e., the contents of a combustibles type bin are 90 percent pure if 90 percent, by volume, of the waste is combustible). Table 6 summarizes the purity data collected during the four-month monitoring program. The sampling matrix generally included the following containers for each source type:

Source Type	Containers
A, F	I, II, IV, V
B, C, D	I, IV, V
E	III
G	IV, V

Information on Type II containers (litter cans) was not consistent because few, if any, were labeled. The identification of Type I, III and IV containers was readily made, but identification of the source types was not as clear. A distinction was made between containers in warehouse offices and those in adjacent storage or packing areas. Similarly, a distinction was made between office and work areas in shops and docks.

Figures 4 and 5 illustrate the variation in combustible material purity from August through November. It is readily apparent from these figures that basewide combustible material purity never fell below some 80 percent. In fact, as sources A, B, and E account for more than 75 percent of the base waste stream, overall combustible purity was consistently estimated to be nearer 90 percent. Only three source G Type IV bins were included in the program. Such bins were readily accessible to contamination by other base activities and were, therefore, not representative of separation effectiveness in the barracks. Those data, therefore, were deleted.

Analysis of the noncombustible fraction showed that purity averaged about 60 percent. Only in the residential and mess areas was there an apparent improvement in purity with time (Table 6). It was observed throughout the sampling program that many personnel disposed of unsegregated waste in the noncombustible containers, thereby demonstrating an emphasis on combustible material purity.

TABLE 5

SUMMARY OF WASTE SORTING SCHEDULE
AT NCBC, AUGUST THROUGH NOVEMBER 1976

Date	No. of Samples	Procedures Used*
8/20	150	V, P
8/30 - 9/1	276	V, P, M
9/15	137	V
9/30 - 10/1	361	V, P, M
10/19 - 10/20	296	V, P, M
11/11 - 11/12	230	V, P, M
11/21	222	V
11/29 - 11/30	238	V, P

* M = Manual sorting
P = Photographic sorting
V = Visual sorting

TABLE 6. SUMMARY OF NCBC SEGREGATION PURITY AS A FUNCTION OF TIME

Source / Date	A Office			B Warehouse			C Shops			D Docks			E Residential			F Mess			G Barracks		
	P_c	P_n	#	P_c	P_n	#	P_c	P_n	#	P_c	P_n	#	P_c	P_n	#	P_c	P_n	#	P_c	P_n	#
8/20	98	80	37/10	95	23	15/3	97	49	10/8	80	55	7/6	88	55	16/3	86	42	17/7	*	*	11/0
8/30	95	59	43/10	92	60	18/12	74	76	13/7	81	28	11/3	79	74	76/30	86	56	32/15	87	75	4/2*
9/15	98	62	21/7	97	73	14/11	91	69	18/8	84	62	10/9	77	32	12/5	94	32	13/13	32	55	4/2*
9/30	97	60	36/22	93	64	32/25	88	79	33/14	84	72	12/12	80	54	78/45	91	40	29/17	77	23	4/2*
10/19	94	43	44/22	94	68	27/19	90	76	32/21	89	67	17/15	74	57	29/20	89	51	27/19	76	45	4/2*
11/11	94	63	21/14	94	86	17/12	93	72	13/17	79	75	10/7	86	73	48/24	94	79	26/18	75	95	2/1*
11/21	99	60	41/15	98	72	16/17	90	78	24/20	80	67	9/8	89	65	13/8	94	50	25/21	83	46	3/2*
11/29	97	69	58/20	90	78	16/18	89	74	17/18	79	76	8/7	86	58	8/4	86	64	35/22	87	58	2/3
Composition	88	12		79	21		65	35		55	45		70	30		79	21		64	36	

P_c = Purity of "combustible" waste, percent by volume

P_m = Purity of "noncombustible" waste, percent by volume

= Number of "combustible" samples/Number of "noncombustible" samples

* = No identifying stickers on some/all containers

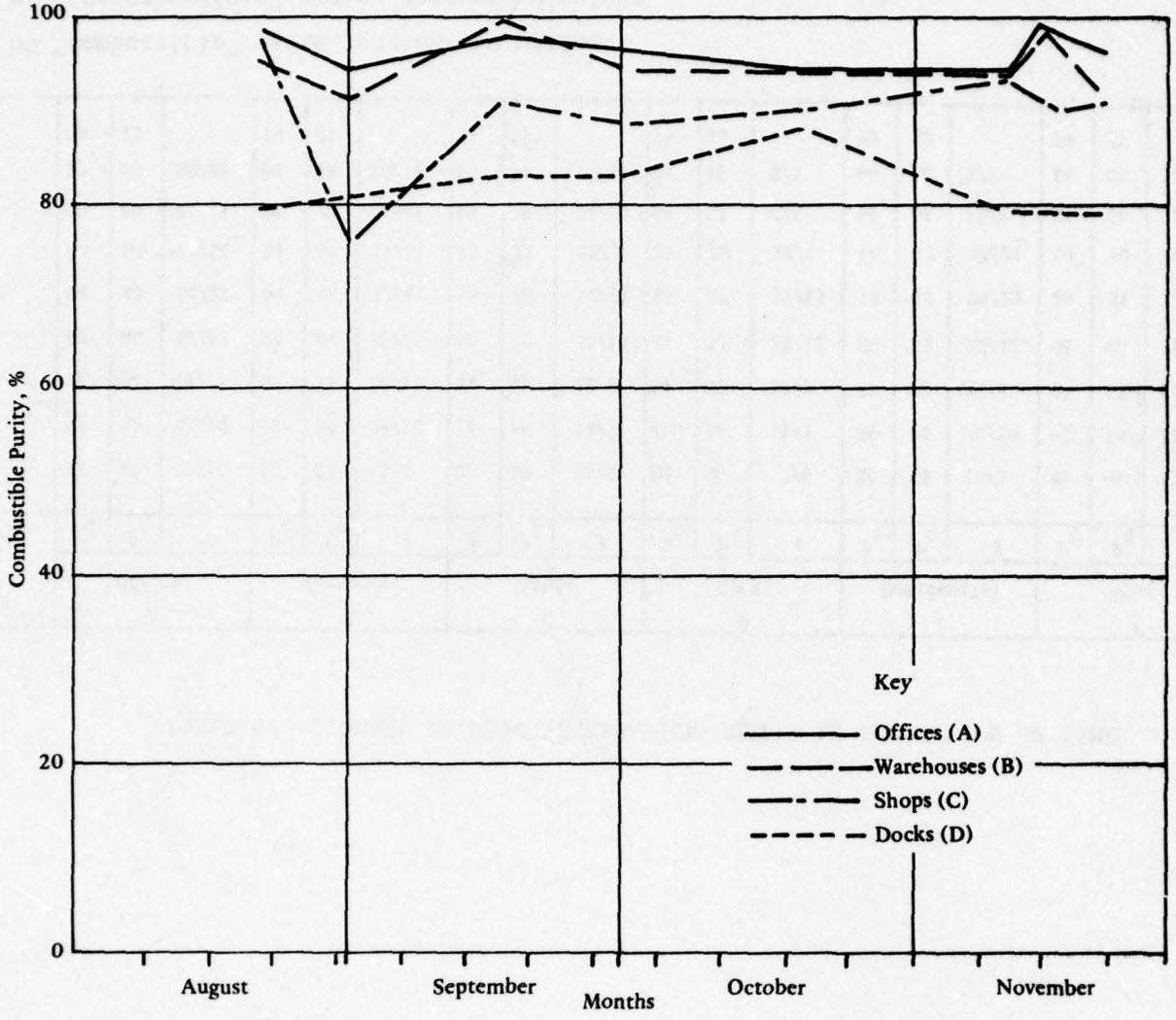

Figure 4. Purity of segregated combustible refuse, NCBC (Sources A-D).

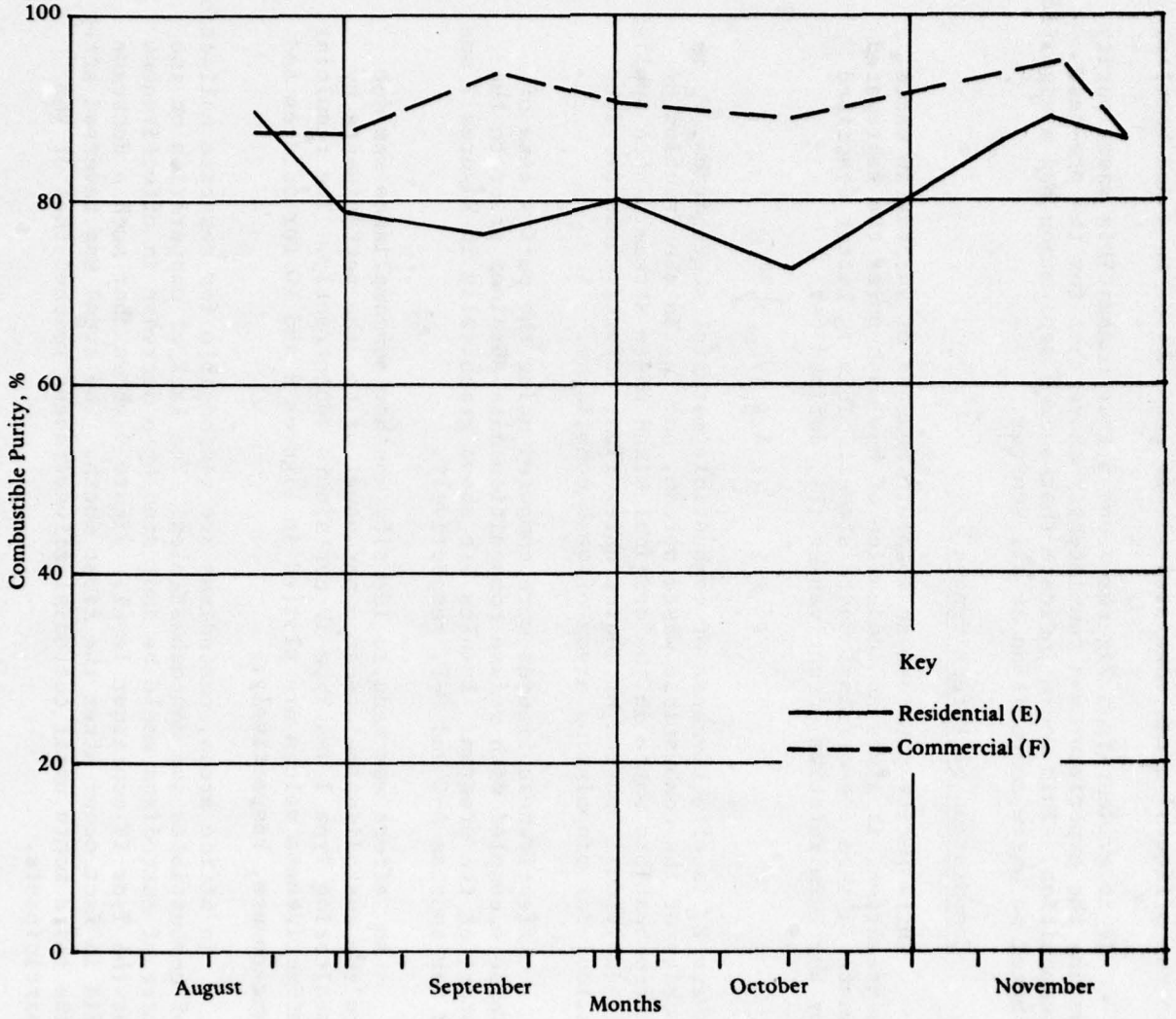

Figure 5. Purity of segregated combustible refuse, NCBC (Sources E-G).

It is interesting to note the difference between combustible refuse purity achieved in the enlisted men's (Bruns Park) and officers' housing areas. Although nearly equal in quantity to Bruns Park, the segregated waste in officers' housing was typically 10 - 20 percent purer (Figure 6). It was also noted that some residents of officers' housing placed more emphasis on purity of conventional recycling commodities (e.g., glass and cans). Several of the noncombustible samples in the officers' areas consisted almost entirely of cans and bottles.

It is evident from Figures 4 and 5 that combustible waste purity during the experiment was consistently above that for the pre-test composition. This would indicate that source separation had a significant impact on waste composition at all sources.

Computation of Effectiveness

While purity provides an absolute measure of success in waste segregation, it gives no indication of how much purer the segregated waste is than the original waste stream. This is better described by the term relative effectiveness (F), defined as:

$$E_c = 1 - \left[(1 - P_c)/C_{nc}\right],$$

where E_c is effectiveness of combustible material segregation, P_c is purity of the combustible waste stream, and C_{nc} is the fraction of noncombustible waste in the original mixed waste stream. When applied to individual sources or source categories, effectiveness provides a tool for pinpointing areas of weak compliance.

Effectiveness figures were computed using the purity data of Table 6, coupled with refuse composition data obtained prior to the start of the program. Results are shown graphically in Figures 7 and 8 for sources A-C and D-F, respectively.

An effort was made to identify whether noncompliance was due to the custodians/maintenance personnel or to the participants by monitoring Type I and Type IV containers concurrently. The resulting effectiveness values are plotted in Figures 9 and 10 for offices and warehouses, respectively.

In office areas, custodians are responsible for separate collection of combustibles and noncombustibles. The lack of cooperation on the part of custodians would be indicated by a decrease in effectiveness at the Type IV container level. Figure 9 shows that such a decrease did in fact occur after the first month. The trend was reversed after the third month until custodial effectiveness reached that of the participants.

Warehouses are not serviced by custodians but must instead rely on warehouse personnel to empty their own Type I containers. Figure 10 indicates a gradual decrease in collector participation, coinciding with a slight increase in personnel participation.

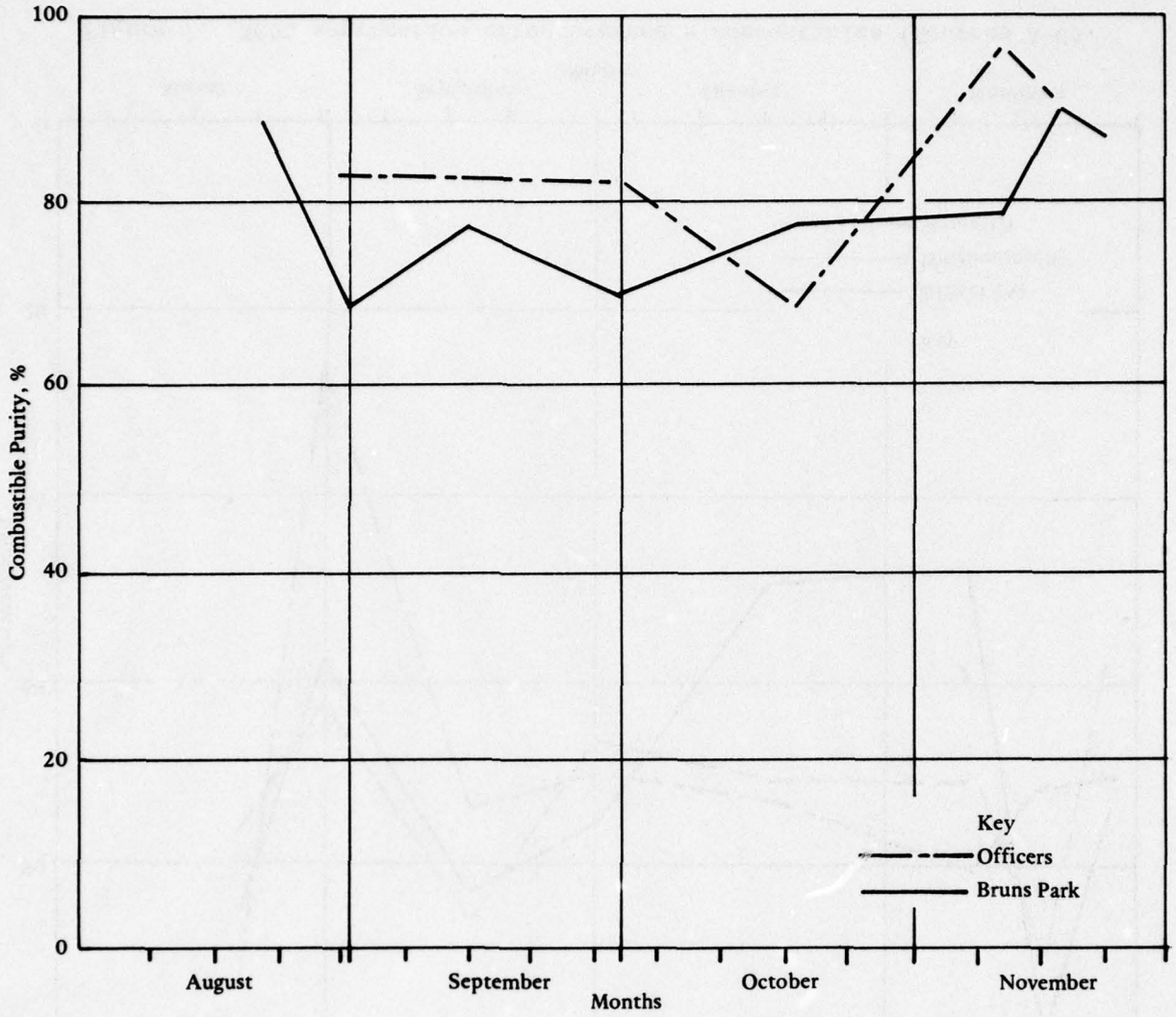

Figure 6. Comparison of segregated refuse purity, officers versus enlisted areas (P_C).

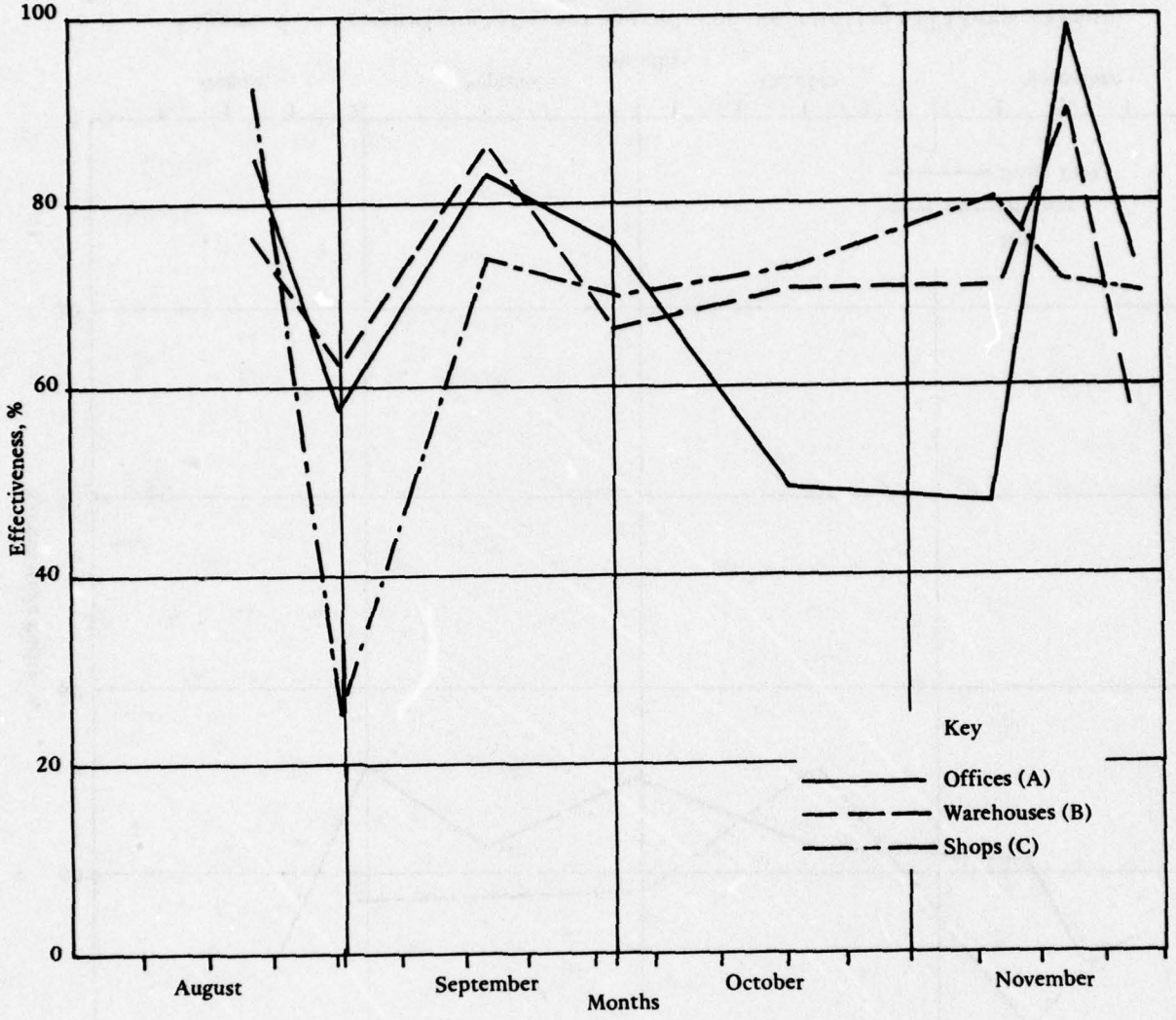

Figure 7. NCBC segregation effectiveness - combustibles (Sources A-C).

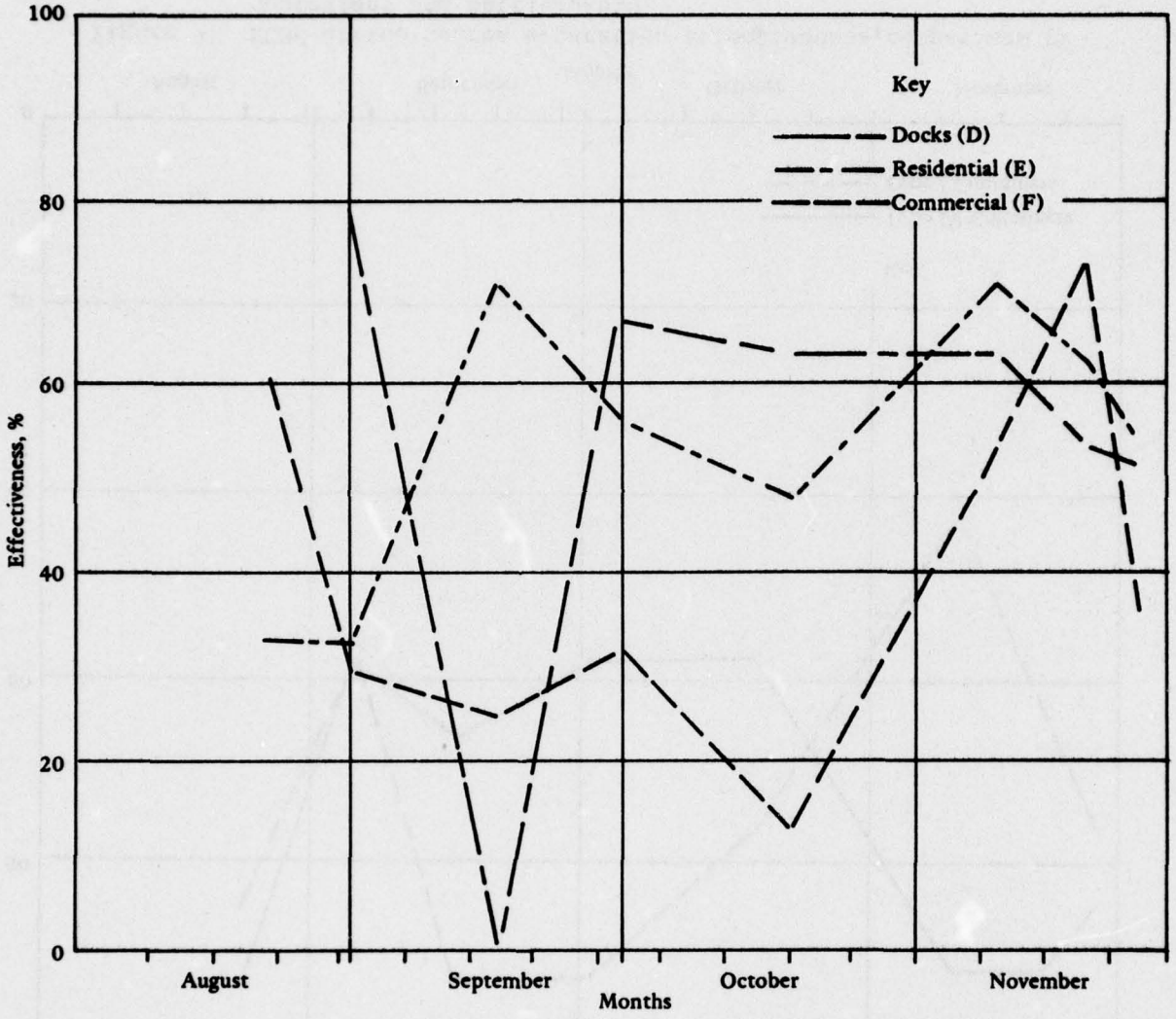

Figure 8. NCBC segregation effectiveness - combustibles (Sources D-F).

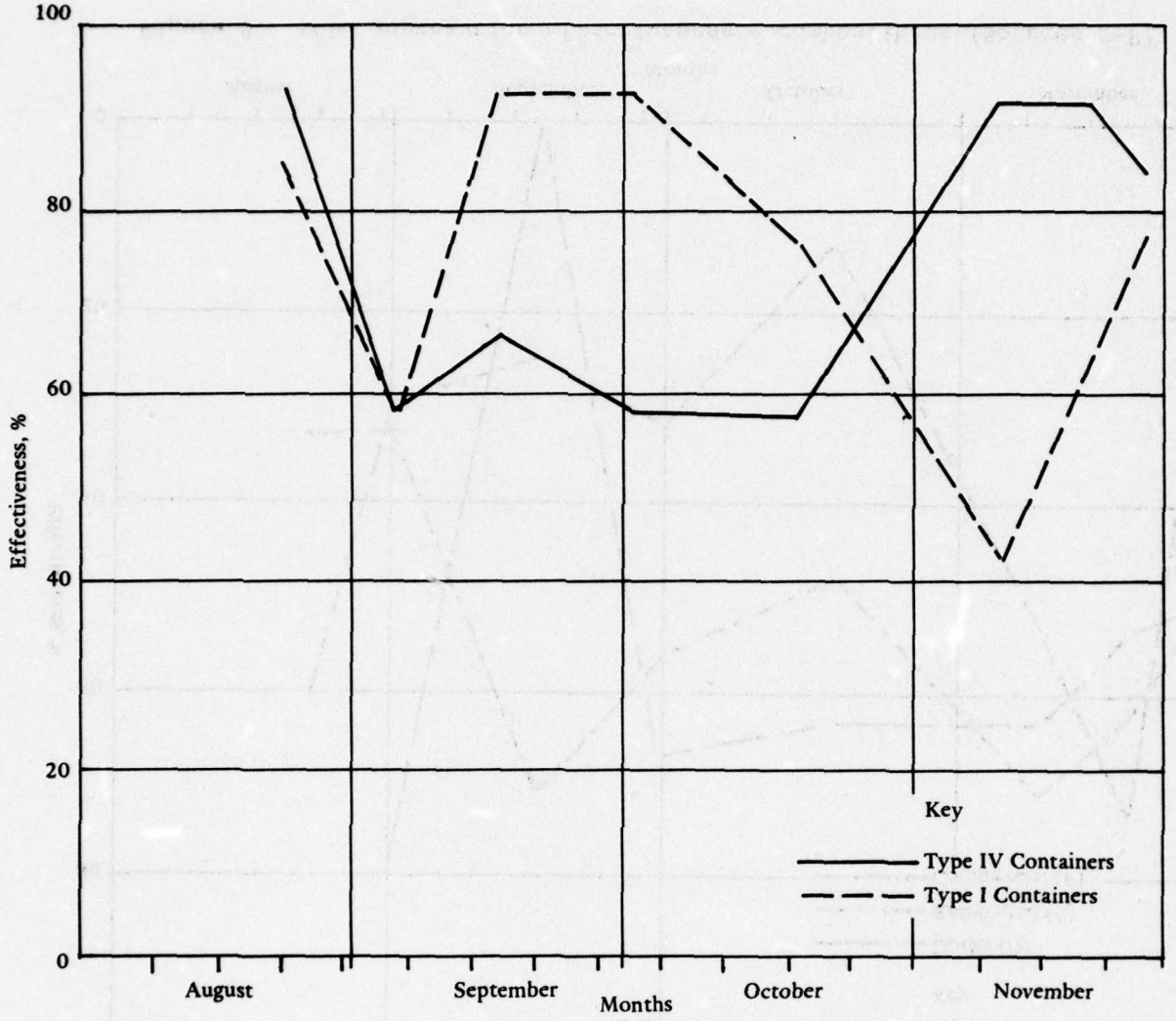

Figure 9. NCBC office source separation effectiveness, comparison of custodians and participants.

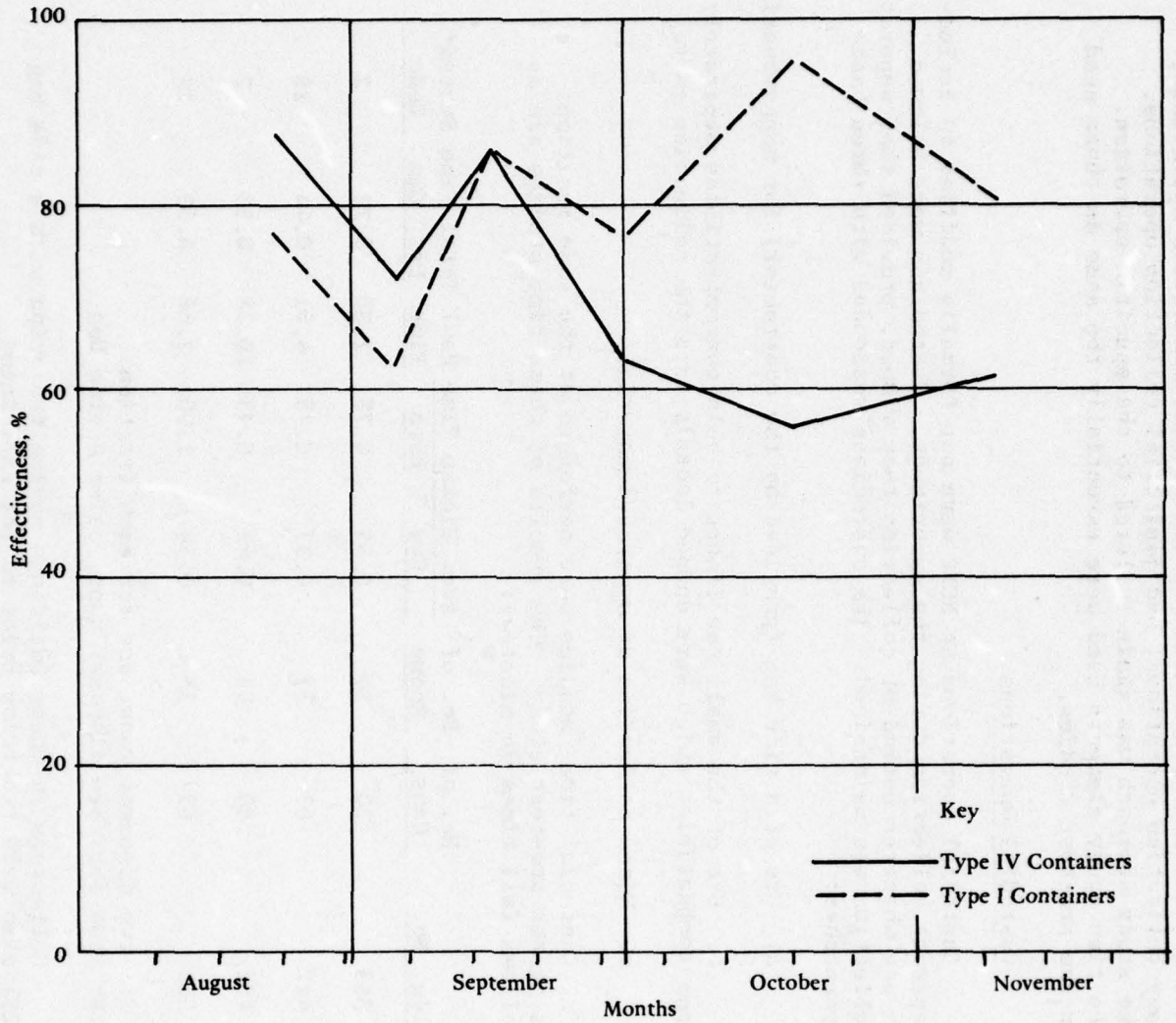

Figure 10. NCBC warehouse source separation effectiveness, comparison of interior and exterior containers.

Time Study of Separate Collection

During the period 18 to 21 October, contractor personnel performed time studies of the refuse collection operations at NCBC. The subjects of these studies were contractor residential collection operations, Navy collection operations, and janitorial collection operations. The study approach was again tailored to the specific operation. The time study elements used were essentially the same as those used in the pre-test studies.

Custodial Operations

Custodial operations at NCBC were not formally modified to include separate collection during the experiment. Custodians were allowed to use whatever method of collection they wished, provided that separate collection was maintained. The custodians responded with three basic approaches:

a. Use of a side bag (provided by the contractor) for noncombustibles.

b. Use of the small can liners to hold noncombustibles separately from combustibles which were dumped loosely into the collection cart.

c. Mixed collection of separated material.

Custodial time studies were performed at the same locations as in the pre-test study. The results of these time studies are as follows (all times in minutes):

Bldg. No.	No. of Cans	No. of Rooms	Ave. Pickup Time Can	Ave. Pickup Time Room	Haul Time	Total Time Per Can	System* Code
363	20	14	0.55	0.78	2.80	0.72	2
442	67	32	0.37	0.78	4.61	0.44	2S
452	80	33	0.41	0.98	10.28	0.53	2
850	65	35	0.54	1.00	2.86	0.59	2S

* 2: two disposal runs, one for each fraction
2S: two separate disposal runs, using a side bag

Collectors in these buildings making two trips with a side bag (2S) also made two trips prior to the experiment.

Time studies of custodial operations at four additional buildings were also performed during the test. The results are (all time in minutes):

Bldg. No.	No. of Cans	No. of Rooms	Ave. Pickup Time Can	Room	Haul Time	Total Time per Can
1218	60	19	0.38	1.21	1.41	0.41
1217	47	22	0.42	0.91	2.24	0.47
1220	60	27	0.40	0.89	1.71	0.44
1221	77	26	0.29	0.86	2.00	0.32

Navy Vehicular Collection

Time studies of the Navy collection activities were performed during the test in much the same fashion as before the test. Collection vehicles monitored included the two front-end loaders and the hoist-and-haul vehicle. Results are summarized in Table 7.

Time studies on the front-end loaders were conducted 18 - 19 October 1976. The time study elements were the same as those used in the pre-test study. It was noted during the study that the collection routes remained essentially unchanged from pre-test operations. In most locations where both hoist-and-haul and front-end loader bins were originally located, the front-end loader bins were labeled for combustibles, and the hoist-and-haul bins for noncombustibles. In some locations where only front-end loader bins existed, a hoist-and-haul bin was added for noncombustibles. Therefore, at such locations the front-end loaders were responsible for the same number of bins at the same locations as before the test. However, at certain other locations, front-end loader bins were replaced with hoist-and-haul bins.

The time study of hoist-and-haul vehicle activities was performed on 19 October 1976. The time study elements were the same as those used in the pre-test study. The unit operations performed by the hoist-and-haul vehicle and the resulting total cycle times were in close agreement with the results of the pre-test study. This was to be expected, as the basic operation did not change (hoist, haul, dump, return, and drop off). The primary change was in routing. Other than certain scheduled daily stops to dump wet garbage, the selection of bins was based primarily on the operators' experience.

Residential Collection

The time study of residential collection operations took place on 18 and 20 October 1976. The collector was timed from the gate to the route, through the route, and from there to the gate. The travel time between segments of the route was also recorded. The total cycle was completed twice each collection day, once for each waste category. The collection frequency was also changed from three times per week to twice per week for the duration of the program.

The results of the time study are presented later in Table 9.

The change from three times per week to twice per week collection during the test may have had an effect on the number of cans placed in front of the home. This would have had an effect on the resulting time per route. However, there is no way of estimating this from the data at hand. Therefore, the extrapolation from twice to three times per week collection was assumed to be linear (i.e., the time for three-times-per-week collection is 3/2 times the time for twice-per-week collection).

Cost Impact of Source Segregation

As discussed earlier, collection costs at NCBC were determined to be a function of three operations:

1. Custodial collection in the various office and warehouse areas.
2. Navy collection of solid waste from base operations.
3. Contract collection of solid waste from the base housing areas.

Because of differences in collection mechanics between operations, the incremental cost of separate collection by each operation was assessed separately.

Custodial Collection Cost

The cost of custodial collection at NCBC is described by the function

$$C_C = L \left(\frac{OH}{100} + 1\right) + E$$

where

C_C = Cost of collection, $/year

L = Labor cost, $/year

OH = Overhead rate, percent

E = Equipment cost, $/year

Custodial collection of solid waste is labor intensive. As the equipment used by the custodians is supplied by the Navy, the cost of the collection contract is essentially a function of labor and overhead. Manpower utilization is, therefore, an accurate measure of the custodial collection contract costs.

The change in custodial utilization was measured by comparing the same custodial routes before and after the program implementation. The time study data are shown side-by-side in Table 8. The overall change in collection time was computed to be +6.8 percent for the four buildings studied. Two of the buildings showed an increase in collection time, one a decrease, and one was unchanged.

TABLE 7. SUMMARY OF SEPARATE COLLECTION TIME STUDY RESULTS - VEHICLES

Vehicle[a]	Load[b]	Time Study Elements (minutes)				Number of Cycles	Total Cycle Time[d] (minutes)
		Maneuver[b]	Travel	Pack[b]	Set-Up		
Front End Loader #1	1.56	0.83	2.12	0.96	0.96	15	4.71
Front End Loader #2	0.91	0.42	1.81	0.90	1.32	19	5.26
Front End Loader #2	0.77	0.67	1.38	0.76	0.84	28	2.65
Front End Loader #2	0.61	0.80	0.76	0.64	0.49	18	2.81

	Hoist Bin	Haul Bin	Dump Bin	Compact[b] (Stationary Compactor)	Return Bin	Drop	To Next Bin	Total Cycle Time[d] (minutes)
Hoist and Haul Vehicle	1.52	6.28	1.31	5.15	7.40	1.04	3.96	(c)

(a) Front End Loader #1: 32 cu yd Pak Mor
Front End Loader #2: 24 cu yd Pak Mor

(b) Average of finite-valued time study elements only (i.e., does not include cycles where element was not performed.)

(c) With compaction: 21.04 minutes
Without compaction: 21.51 minutes

(d) Average of all cycles

TABLE 8

MOTION/TIME ANALYSIS-CUSTODIAL OPERATIONS
NCBC PORT HUENEME
(all times in minutes)

Bldg. No.	Relation to Program	Average Pickup Time Can	Average Pickup Time Room	Haul Time	Total Time Per Can	Percent Increase (Decrease)
363	Before(1)[a]	0.66	1.17	1.56	0.72	0.0
	After (2)	0.55	0.78	2.80	0.72	
442	Before (2)	0.47	1.10	3.76	0.53	(17.0)
	After (Side,2)[b]	0.37	0.78	4.61	0.44	
452	Before (2)	0.40	0.93	1.53	0.42	26.2
	After (2)	0.41	0.98	10.28	0.53	
850	Before (2)	0.44	0.91	3.63	0.50	18.0
	After (Side,2)	0.54	1.00	2.86	0.59	
					Average	6.8%

a. (1) : makes one trip to type IV bin to unload waste.
(2) : makes two trips to type IV bin to unload waste.
b. (Side) : uses side bag for noncombustibles.

Two collection methods predominated: (1) a separate trip through a route for each waste category, and (2) a single collection trip for both waste categories, with noncombustibles placed in a side bag (provided by the contractor).

The two custodians using side bags showed almost no change on the average between pre-test and separate collection operations. The custodian employing the two-run approach both before and during the program experienced the largest increase in collection time (26 percent). The custodian switching from a single run to two separate runs experienced no change in collection time. Because the side bag technique proved to be the most efficient, it is assumed that a continuing program would utilize that technique (Buildings 442 and 850). From Table 8, the average recorded change in janitorial collection time for the side bag technique was a 0.5 percent increase. However, because of the small number of data points (two) and because of the wide spread between those points, the confidence associated with this figure (0.5 percent increase) is very low. In view of this low confidence level, individual custodians who had participated in the test were questioned and it was decided to use the arbitrary, but conservative range of 0.5 to 5 percent increase for the cost impact summary presented later in this report.

The custodial contract cost at NCBC is $860,000 per year. Of this, an estimated $154,800 is allocated for trashing and dusting operations in base office buildings. Based upon an average increase in collection time of between 0.5 and 5 percent, NCBC would realize an increased cost between $64 per month and $645 per month for the custodial contract. When added to the other cost impacts of source segregation, these increases result in a total cost impact per ton of refuse between $1.64 and $2.95.

Residential Collection Cost

The cost of residential solid waste collection at NCBC can be described by the function

$$C_R = L \left(\frac{OH}{100} + 1\right) + E$$

where C_R is the cost of the residential collection contract and the other variables are as before.

The labor cost is dependent upon the amount of time spent on the NCBC collection route. Collection time is the summation of (1) time spent on the actual route, (2) time spent traveling between routes, and (3) travel time to the base and from the base to the landfill.

A comparison of the pre-test and in-test time studies is shown in Table 9. Several clarifications and changes in the collection model must be made to properly analyze the system:

1. Inasmuch as the source segregation program was intended for implementation only with an on-base resource recovery plant, the cost impact being evaluated reflects only the on-base travel times, and not

TABLE 9

ANALYSIS OF DAILY RESIDENTIAL SOLID WASTE COLLECTION TIME STUDIES

NCBC PORT HUENEME

Item	Pre-Test Study*		In-Test Study*	
	Officers	Bruns Park	Officers	Bruns Park
Total Collection Time (tc)	60.0	40.0	--	--
. Combustibles	--	--	39.7	46.4
. Noncombustibles	--	--	11.7	26.6
SUBTOTAL	100.0		124.4	
Travel Time (t_t)				
. Gate to route	1.6		1.6	
. Between routes	0.9		1.8	
. Route to gate	3.4		3.4	
. Yard to NCBC	25.0		25.0	
. NCBC to landfill	20.0		20.0	
SUBTOTAL	50.9		51.8	
Total Time/Day ($t_t + t_c$)	150.9		176.2	
Percent Change			16.8	(increase)

* All time in minutes.

the off-base travel times (e.g., Yard to NCBC or NCBC to landfill). For this reason, these off-base travel times are assumed not to change (i.e., they would not affect the eventual cost analysis).

2. The collection route is divided into three distinct sections: (1) officers' housing, (2) chiefs' housing, and (3) the Bruns Park family quarters. Time between routes refers to the travel time between these sectors.

3. Officers' collection time refers to officers' and chiefs' housing.

4. Throughout the program, the contractor performed collection on Monday and Wednesday mornings. Before the program, collection was also performed on Saturdays. The switch to twice per week collection obviously is a saving to the contractor, and should be reflected in the contract. It is possible that due to the decreased waste load in some bins, three-times-weekly collection would result in fewer pickups per stop. However, it was assumed that all bins would be emptied regardless of their contents.

Based on these assumptions, the separate collection resulted in an overall 16.8 percent increase in collection and hauling time for residential collection. Unit collection costs were not available from the residential contractor. To determine the actual economic impact on residential collection would require a detailed analysis of the system, which is beyond the scope of this study effort. Therefore, it was assumed that collection costs are a linear function of collection time. The normal collection contract costs NCBC $1,250 per month. The 16.8 percent increase in collection time is equivalent to a $210 month increase in the collection contract costs.

Navy Collection Cost

The cost of Navy refuse collection is a function of the operation of the two front-end loaders and one-hoist-and-haul vehicle.

Front-end loader collection was unaffected by the program. As noted earlier, the number of bins and time per cycle for hoist-and-haul collection remained essentially unchanged as a result of the program. Hence, there is no incremental cost of separate collection by the hoist-and-haul vehicle.

Other Cost Impacts Attributable to Source Segregation

Other costs affected are those related to the need for additional containers, public relations, labels and program administration. One hundred forty-eight additional outdoor containers were needed; these are estimated to cost $300 each and to have a useful life of 20 years. Approximately 75 indoor containers were needed at a cost of about $30 each, with a useful life of 5 years. The capital recovery factor for 10% compound interest is 0.117 per year for 20 year life and 0.264 per year for 5 year life. Therefore, for the additional outdoor containers, the cost impact is

$$(CI)_o = \frac{\$300}{\text{container}} \times 148 \text{ containers} \times \frac{0.117}{\text{yr}} \times \frac{1 \text{ yr.}}{12 \text{ mo.}}$$

$$= \$433 \text{ per month.}$$

Similarly, the cost impact for the additional indoor containers is

$$(CI)_i = \frac{\$30}{\text{container}} \times 75 \text{ containers} \times \frac{0.264}{\text{yr}} \times \frac{1 \text{ yr.}}{12 \text{ mo.}}$$

$$= \$50 \text{ per month.}$$

The remaining cost impacts have to do with the expenses of public relations, container labels, and finally, program administration. The combined cost of these items is estimated at $100 per month.

Table 10 summarizes the cost impact, increase or savings, in NCBC collection operations as a result of source segregation.

FOLLOW-UP HUMAN FACTORS SURVEY

Surveys were conducted to examine the results of source segregation in three distinct populations: base residents, base employees, and trash collectors. These surveys were designed to elicit and examine experiences during the test, measure attitudes toward source segregation, investigate areas of resistance, determine penetration of the campaign and campaign materials, measure acceptability of campaign materials, examine irregularities occurring during the test, investigate reactions and resistances to an altered pattern of source segregation, seek suggestions for project methodology improvement, and determine trash collection habits of employees at home, residents at work, and trash collectors at home. Sample populations were selected, appointments were scheduled where possible, the sample populations were interviewed, interview results were tabulated, the survey results were interpreted, and a report was issued by the contractor.[6] This section is a summary of the contractor's observations arising out of the findings of this survey.

Employees/Residents

Means of Introduction

The means by which participants were introduced to the project appears to have had significant effect on their compliance. The initial reaction to the means of introduction was found to be still operative during the interviews, which occurred six to eight months after project initiation. Positive effects were evident among those participants (employees and residents) who first heard about the project through person-to-person contact. Negative attitudes were aroused when cans and labels were received before the project was publicized and explained by other means. Properly sequenced introduction seems to have been a significant factor.

TABLE 10

SUMMARY OF SOURCE SEGREGATION
COST IMPACTS

NCBC, PORT HUENEME

Operation	Projected % Increase	Projected Cost Increase/(Savings), $/month
Custodial Services	0.5 to 5	64 to 645
Residential Collection	6	75
Additional outdoor containers		433
Additional indoor containers		50
Program administration, public relations, labels, etc.		100
TOTAL		722 to 1,303

$$\text{Total per ton} = \frac{\$722 \text{ to } \$1,303}{21 \frac{\text{tons}}{\text{day}} \times \frac{21 \text{ days}}{\text{mo}}} = \$1.64 \text{ to } \$2.95 \text{ per ton}$$

Prior attitudes of those who first learned about the project through printed or visual media did not seem to undergo modification based on the content of the material. In offices, when supervisors had been the source of the person-to-person introduction, subsequent lack of reinforcement by the supervisor appears to be correlated with decayed compliance.

Total name recognition for the project (Project TRASH) was not achieved. Thirty percent of the participants did not recognize the project by name, but did recognize it by description.

Emphasis on the residential component in the Coverall articles appears to have convinced a number of base employees that the project was for residents only. It should be noted that a higher percentage of employees read the Coverall than do residents.

Response to hearing of the project through the wives' clubs appears to have been positive. Response to the film shown at the base theatre immediately before commercial movies appears to have been strongly negative. The Housing Office seems to have indoctrinated newly arrived residents in accordance with project guidelines. Response to the Housing Bulletin (76% of interviewees freely mentioning this communication channel) was quite strong.

Labels

Shortcomings in label distribution seem to have had a significant effect on compliance. Twenty-five percent of the employees received no labels for their inside containers; 43% of the residents received only the single label, "No Paper, Plastic or Cardboard." The single label did have some effect on resident compliance; the lack of any inside labels, coupled with the emphasis on housing found in the Coverall, critically reduced employee compliance.

Many respondents expressed the need for more explicit instructions. Suggestions included enumerating articles for each container in greater detail; using pictures to explain what should go in each can; making instructions positive rather than negative (no paper, plastic or cardboard). This latter response occurred a number of times. The "X" on the label was recalled frequently, and with significant objection. Dissatisfaction was expressed with the similarity of size, shape and colors of the labels, and with the fading of the colors. Larger, more noticeable labels were frequently suggested; color coding of containers occurred regularly, and appears consistent with Navy practice. When office cans were turned to the corner of the wall, or toward the wall, the label was no longer visible; the label was also not visible to someone standing directly over the container, a situation occurring frequently. Base residents often asked that labels be created with children in mind. As contrasted with posters, which are discussed later, labels seem to be an effective reinforcement of compliance.

Additional inputs from participants suggested a continuous message around the container, and expanded basic information about the project

to be printed on an additional label, since the container presents an on-the-spot, highly visible means of displaying information.

Containers

A significant number of employees complained about the location of one or the other of the two containers. A frequent comment was that that the ratio of "burnable" to "non-burnable" containers was not realistic in terms of the type of trash generated by that particular facility. A recurring suggestion was that there be a specially designed container for the deposit of both kinds of trash by employees, thereby requiring only one type of class I office container.

The answers of Petty Officer residents were contaminated by their prior and ongoing attitudes toward the dumpsters. Frequently mentioned by these interviewees was the basic difficulty experienced by the children in taking refuse out to the dumpster. Several respondents expressed resentment of the Chief Petty Officers' receiving an additional (orange) lightweight garbage can. Some respondents described the orange container as too lightweight and fragile, although its light weight appears to have been a distinct advantage as was its different color.

Information

While the majority of respondents stated that they had sufficient information to know what was expected of them, even those who made significant misinterpretations of project procedures and purpose gave the same answer. The admission of having insufficient information appears to have been a difficult one for many respondents.

Problems

Interviewees indicated a lack of information was a prime difficulty in separating. Confusion was expressed on the interpretation of separation guidelines. One such confusion was with the handling of marginal or mixed materials, such as leaves or plastic coated wire. Expression of irritation with the inconvenience was prevalent, but occurred most often at a low level of intensity. Problems with children occurred at every phase of separation, in every stratum of residents. It is interesting to note that parents of educationally handicapped children, accustomed to focusing on the teaching of their children, regarded separation as only one more challenge, and had no problems with their children. Clearly, prior attitudes appear to define attitudes toward problems, as well as toward the project as a whole.

Irregularities

Decay of compliance over time was observed by a number of participants. Participant awareness of custodians or trash collectors mixing

separated trash also served to decay compliance. Many of the Petty Officers interviewed reported almost no cooperation from residents of Petty Officer Housing. An impressive majority of these respondents defined themselves as one of the few families in their area actually cooperating with the project. The attitudes of supervisors strongly affected the compliance of employees.

The CBC Coverall

A frequent response from many participants was that readership of the Coverall is limited only by its distribution. Residents who had read about Project TRASH absorbed more information than did employees, even though percentage of readership for the two populations is comparable. This may indicate a readiness to focus on local events on the part of residents which is not present in employees.

Posters

There were frequent suggestions aimed at increasing the impact of the posters: using bright colors, having more than one poster design, changing posters, choosing a more dramatic theme. There was general awareness of the posters, but a widespread lack of response to them. Few people mentioned posters as one of the means by which they heard about the project. Many of the positive responses to the posters were in actuality responses to the project.

Improvements

Most respondents made constructive suggestions on project improvement. Many responses focused on motivation, and considered message content, as well as a more coercive message. Rewards for compliance, and punishment for non-compliance were suggested. Need was expressed for a more coordinated campaign, and for more reinforcement by information communication during the project. Label changes and trash container changes were suggested. Willingness to make constructive criticisms and to recommend improvements was noted even in those interviewees who expressed hostility to the project.

Glass and Metal Separation

A number of those interviewees who responded that a glass-and-metal-only separation scheme would be more difficult than the project just completed, appeared to have little grasp of the question. Several of these interviewees expressed concern over glass breakage in the combination of glass and metal.

General Attitudes

Implicit in many answers is the wish of the respondent that the project succeed: that people comply, that the project prove to be cost-effective, that it pass from the test phase to the operational phase. The vast majority of participants were strongly positive towards the concept, and only slightly less positive toward the project itself.

Recall of Project Objectives

The greater recall of project objectives on the part of base residents again appears to indicate that residents are more involved in base projects than base employees. Lack of awareness of objectives did not interfere with compliance.

Custodians/Trash Collectors

Project Name Recognition

Halfway through the interviews, it was observed that the janitorial contractor was selecting interviewees by a screening process. This process consisted of asking the potential interviewee if he had been working at the time of Project TRASH introduction, and then providing a very brief project description. The screening process, while totally non-prejudicial, did not permit project name recognition testing. No other answers were affected by the screening process.

Attitudes of Employees/Residents and Custodians/Trash Collectors

The participant attitude most often reported by custodians/trash collectors was strongly negative. Most custodians/trash collectors, on the other hand, described their own attitudes as being positive and cooperative. A number of custodians identified totally with the project, even to the extent of assuming responsibility for persuading participants to comply. The attitudes of these employees seemed to reflect the attitudes of management of the janitorial and collection contractors (Geronimo Service Co. and E. J. Harrison and Sons). Both contractors proved to be totally cooperative and supportive throughout the survey.

Problems and Difficulties

Source separation appears to have increased the effort required for all custodians/trash collectors. Statements to the contrary on the part of several of these interviewees appears to be contradicted in other parts of the survey questionnaire. This increased level of effort does not appear to affect their willingness to make constructive criticism, or recommendations for project improvements. When asked what changes would make it easier for the custodians, a significant number responded that increased compliance on the part of participants would make their job easier.

Goals and Objectives

While the majority of respondents did not have a total grasp of project objectives, this seemed to have little effect on the positive attitudes they generally displayed.

Containers

A number of recommendations had to do with the placement or design of containers, or their processing. These included having containers side by side, having larger containers in local or central locations for non-burnables, and having containers gathered to a central place by employees. Concern was expressed over cardboard boxes, and suggestions were offered to solve the problem of outdoor containers filling too rapidly with uncrushed cardboard boxes.

Proposed Project Modifications

Almost without exception, custodians defined two rolling cans as more work, and more time consuming. Recommendations and responses to other questions support the use of a smaller, lighter collection container for non-burnables, or having the present rolling can compartmentalized.

The idea of an additional bin mounted on the collection truck was rejected by the trash collectors, but the possibility of a two-compartment truck was discussed, with a positive response.

CONCLUSIONS

1. Two-component voluntary source segregation of solid waste for waste heat recovery, is workable in the Navy shore establishment.

2. Typical purity of the source-segregated "combustibles" fraction was 90%. The cost increase of solid waste management due to source segregation was between $1.64 and $2.95 per ton (an increase between three and six percent of the total solid waste cost for equipment and labor for collections, storage and disposal).

3. Various implementation problems contributed to a relatively low purity for the source-segregated "noncombustibles" fraction. Most of these problems can be readily solved, thereby providing for a considerably higher purity for this waste stream. This, in turn, enhances the prospects for cost-effective materials recovery.

4. Time studies of custodial refuse collection showed that certain separate collection techniques are more efficient than others. Specifically, custodians employing a side bag for the second waste category were 18 percent more efficient[2] than those making a separate collection run for each category.

5. By analogy to custodial collection operations, the use of a single run by a compartmentalized collection vehicle should improve separate collection efficiency in the residential areas (a contractor function).

6. Navy collection operations were not significantly affected by source segregation.

RECOMMENDATIONS

1. Two-category source segregation of solid waste, with emphasis on separation of the combustible fraction for waste heat recovery, should be considered as part of future plans for Navy shore installation solid waste resource recovery.

2. The need for Navy emphasis on waste heat recovery, as opposed to materials recovery, should be communicated to the U.S. Envrionmental Protection Agency (EPA) Office of Solid Waste Management Programs (OSWMP). This would tend to balance the emphasis of the EPA guidelines[3] (for source separation) on materials recovery at all Federal agencies.*

3. Further RDT&E on solid waste source segregation methods and approaches is recommended to determine optimum waste category definitions, public relations campaign structures and other related aspects of source segregation at Navy shore installations if segregation of refuse is implemented.

*It is important to note that the solid waste source segregation experiment at NCBC, Port Hueneme was conceived, planned and implemented prior to promulgation of the EPA guidelines on source separation. It is for this reason that the experiment does not reflect or relate to the EPA guidelines which prescribe the recovery of high grade paper from offices, and newspaper, aluminum cans and mixed glass from residences. However, it is also important to note that the typical reduction in total energy available in solid waste due to paper removal in recycling programs has been shown to be less than 10 percent[8]. Therefore, although a basic waste heat recovery program could be successfully supplemented with a waste materials recovery program, it is imperative to note that there is a high risk factor involved. The risk incurred is the potential failure of both recovery programs due to the shift from the recommended two-component source separation to a three (or more) component source separation. The additional component is due to the need for separation of high quality paper from the combustibles, and as explained in reference 1, a successful source separation program is particularly difficult to achieve with three or more waste categories.

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APPENDIX A

PLACEMENT AND LABELING OF CONTAINERS

Outdoor Containers

In the survey of NCBC, 307 outdoor containers were found to be in use. Applying the requirement of a minimum of two containers at each disposal location to provide for waste segregation, one might expect this number to be approximately doubled to a requirement of over 600 containers for the segregation experiment. However, it was determined that a total of only about 455 containers will be required. At some locations where there are now two or three containers, relabeling of existing containers will suffice, or alternatively the addition of only one container for the noncombustible category will be adequate. An example of this may be seen in Figure 1 of this report, which shows for Building 477 (bottom center) that there were originally three bottom-drop containers; instead of doubling to six for the segregation experiment, one of the original three will be replaced by a top-dump container (for combustibles).

Indoor Containers

In labeling the indoor containers (e.g., office wastebaskets) for segregation of waste into the two categories, a general philosophy to be followed for the convenience of the using personnel is that in no case should there be more than twenty paces between the containers for the two types of refuse (i.e., "only paper, plastic and cardboard" and "no paper, plastic or cardboard").

The placement of labels on the existing indoor containers (to be performed by the janitorial personnel) shall follow these criteria:

Number of Containers Now in a Room	Label	
	Only PPC*	No PPC
1	1	0
2	1	1
3	2	1
4 or more	2 or 3 "Only PPC" with each "No PPC," where possible without violating the above 20-pace separation limit.	

The janitorial contractor has estimated that preparation for and performance of their part of the segregation experiment will entail additional costs as follows:

Labeling indoor containers	$1800 (one-time cost)
Maintaining segregation in disposing of the waste	$3750 per month

*PPC = paper, plastic, and/or cardboard

APPENDIX B

N68305-76-C-0028

STATEMENT OF WORK

Experiment on Source Segregation of
Solid Waste at Navy Shore Installations

SECTION 1. SCOPE OF WORK

1.1 Objective:

Quantify (1) segregation effectiveness, at a typical Navy base, (2) purity of source segregated solid waste, and (3) estimated percentage increase in operation and maintenance costs attributable to source segregation.

1.2 Background:

The Civil Engineering Laboratory (CEL), under the sponsorship of the Naval Facilities Engineering Command, will conduct an experiment on source segregation of solid waste into essentially combustible and non-combustible fractions at the Naval Construction Battalion Center (NCBC), Port Hueneme, CA. The combustible fraction will be defined as wood, paper and cardboard, while all other materials will comprise the non-combustible fraction. This experiment is designed to resolve questions of workability of source segregation and provide a quantitative basis for evaluation of the cost effectiveness of source segregation as it impacts total solid waste management systems at Navy shore establishments.

CEL will make all necessary arrangements and preparations for the conduct of the source segregation experiment.

Measurement of degree of segregation achieved and determination of additional cost in gathering and collection due to segregation shall be undertaken by the contractor, over a period of four months, as described below.

1.2.1 Classification of Container Types

The following definitions for refuse container classes will apply throughout this work statement and the subsequent contract.

Class I - Interior building (office, barracks, warehouse, storage, etc.) containers such as small waste baskets, cafeteria trash cans, kitchen containers, 30 gallon galvanized warehouse barrels, etc., but excluding family housing interior containers.

Class II - Outdoor containers which are not picked up by trucks, i.e. the containers primarily found along outdoor paths and small buildings. These containers are emptied into Class III containers for pick up.

Class III - Residential outdoor containers, i.e. 30 gallon up to one cubic yard residential.

Class IV - These containers are picked up by refuse trucks. There are three basic types (front loading, side and bottom truck lift slotted, and Dempster Dumpster).

Class V - Refuse trucks, i.e. front loading, side and bottom lifts and rear loading Dempster Dumpster.

1.2.2 Classification of Solid Waste Sources

The following classifications for refuse sources will apply throughout this Statement of Work.

Source A - Office Space

Source B - Warehouse, storage buildings, receiving buildings

Source C - Shops, e.g. metal working, carpentry, mobile equipment maintenance and repair

Source D - Docks

Source E - Residential

Source F - Mess hall, Officer's Club, cafeteria, comissaries, service facilities, etc.

Source G - Barracks

1.2.3 Definitions and Nomenclature

$V_{n/m}$ = volumetric ratio of noncombustibles to total refuse (before segregation).

$V_{c/m}$ = volumetric ratio of combustibles to total refuse (before segregation).

P_c = (segregated) volumetric ratio of combustibles in combustibles container to total refuse in combustibles container.

= purity of combustibles container.

P_n = (segregated) volumetric ratio of noncombustibles in noncombustibles container to total refuse in noncombustibles container.

= purity of noncombustibles container.

$E_c = 1 - [(1 - P_c) / V_{n/m}]$ = source segregation effectiveness for combustibles containers.

$E_n = 1 - [(1 - P_n) / V_{c/m}]$ = source segregation effectiveness for noncombustibles containers.

1.3 Applicable Documents:

The following enclosed documents form a part of this Statement of Work to the extent specified herein.

(1) Map of Naval Construction Battalion Center, Port Hueneme, CA.

NOTE: A map of NCBC, Port Hueneme, with refuse sources identified by class per section 1.2.2, and with numbers and classes of containers indicated, will be furnished.

(2) "Summary of Sort Procedures for Mixed Municipal Waste; Manual and Photographic," Dec. 1975, Systems Technology Corp., pp. 21-27 (Photographic Sort Procedure.)

1.4 Performance Requirements

The contractor shall furnish all personnel, material, facilities and equipment required to complete the effort specified in this statement of work. The following tasks are included in this effort.

1.4.1 Task 1. Survey of Source Segregation Effectiveness

Upon commencement of the source segregation experiment, the purity of container refuse shall be surveyed and recorded by the Contractor, using the data sheet format of Table I. The survey shall be continuous, on a biweekly basis over a period of four consecutive months, sampling containers randomly but within the schedule defined by Table I. This Table specifies the number of containers of each class to be checked at each source by way of the number of data entry spaces available; only one of each source type will be checked, each within a two week period. The experiment will be conducted so that one month of surveying will elapse prior to the start of source segregation so as to provide a basis for comparison. Completion of the survey shall be in accordance with the attached Milestone List.

The container classes I through V and refuse sources A through G are defined in sections 1.2.1 and 1.2.2, respectively. Purity is defined in section 1.2.3.

To determine the degree to which the solid waste has been separated at the source into a "combustible" fraction comprised of wood, paper and cardboard, and a "non-combustible" fraction comprised of all other materials, the following procedures will be employed in connection with the particular class of storage container indicated. Also, it is desired that contaminants (impurities) of either of the two "segregated" waste categories be identified without necessarily being quantified, e.g. newspaper, books, magazines, old lumber, food waste, beverage cans, beverage bottles, packing material, etc. Provision is made for recording such observations on the data sheet format of Table I.

1.4.1.1 Survey Procedure for Container Classes I, II, and III

Periodic surveying of source segregation at these classes of containers will require that the contents be completely emptied* and spread out into an approximately rectangular array of minimum thickness, so that all items are readily identifiable. The volume occupied by the contaminants is estimated, subtracted from the total volume, and the difference divided by the total volume to produce a numerical estimate, in percent, of the "purity" of the segregated refuse, i.e. P_c or P_n, as appropriate.

Contaminants are to be identified by type without necessarily being quantified.

1.4.1.2 Survey Procedure for Container Class IV

In order to survey the effectiveness of source segregation at these containers, their contents are to be inspected at the time of transfer, or emptying, into the collection truck. CEL will supply a front loading refuse collection truck, along with an operator, for this purpose. With the truck empty, contents from one of the containers will be loaded into it. They (the container contents) will then be spread out manually into a uniform layer of minimum thickness within the confines of the truck bed. All items should be readily identifiable. The "purity", P_c or P_n, of the refuse is numerically estimated as before in section 1.4.1.1. Successive container loads shall be inspected in similar fashion except that, before loading into the collection truck, the prior loads will be compacted and covered so as to provide a clear area within the truck bed.

*The rectangular residential blue containers equipped with bottom lifts for mechanized handling are best emptied by use of a large shovel.

1.4.1.3 Survey Procedure for Container Class V

Periodic surveying of the effectiveness of source segregation at Class V containers (collection trucks) will consist of photographic documentation of the truck contents after dumping at a landfill site. Following a dumping directly on top of cover soil, the contents should be spread by a bulldozer to an approximately uniform thickness so as to uncover any concentrations of contamination of the segregated waste material. This done, plan view photographs of the refuse shall be taken at a distance no greater than six feet, and analyzed using the grid technique described in enclosure (2). This analysis will produce the required estimate of the "purity", P_c or P_n, of the refuse.

In addition, the contractor shall refer to data from the landfill records for weights of truckloads of the combustible fraction and of the noncombustible fraction of refuse. The contractor shall transcribe this data during the source segregation period on a weekly basis.

1.4.2 Task 2. Assessment of Source Segregation Impact on Cost of Collection Operations

Data pertaining to increases in operating costs attributable to source segregation shall be acquired as described in sections 1.4.2.1 and 1.4.2.2. These data are to be expressed as percentages of cost increase in the categories of labor, equipment utilization, any and other significant cost categories.

1.4.2.1 Manpower and Equipment Survey, Non-Segregated Refuse

For a two week period at the start of the contract, but prior to the start of source segregation, the contractor shall perform time and motion studies, on a random sampling basis, of the labor, equipment utilization and any other significant operating cost categories for collection at each of the source types A through G. Data shall be recorded using the data sheet format of Table II. A single time and motion study at an individual source shall consist of the contractor personally monitoring the collection of refuse from all containers (of classes I through IV) within the particular source, or facility, timing the process and manpower loading from start to finish. Each source type is to be monitored in this fashion three times during the initial two week period. Facilities selected to represent each source type shall not be monitored more than once. For purposes of the Statement of Work, "finish" of the collection process means that all of the class IV containers within the particular source being monitored have been emptied into the collection truck.

1.4.2.2 Manpower and Equipment Survey, Segregated Refuse

During the third or fourth month of the source segregation experiment, the contractor shall repeat the survey described in section 1.4.2.1, at the exact same facilities.

1.4.2.3 Evaluation of Cost Differential

Based on the results of sections 1.4.2.1 and 1.4.2.2, the contractor shall prepare a tabulation of actual values and percentages of manpower and equipment utilization differentials, and then compute cost differentials for each source type. Labor and equipment utilization rates will be furnished by CEL. The Contractor shall then use this information, along with the map described in the note of section 1.3.1, to extrapolate a value for the total NCBC base cost differential (on the basis of numbers and classes of containers).

1.5 Reports

1.5.1 Daily Reports

The contractor shall furnish a map of NCBC on each working day, which shall indicate his approximate location for that day.

1.5.2 Progress Report. The Contractor shall furnish six (6) copies of a Progress Report to the Officer in Charge of Contracts by the fifteenth (15th) day of each month after the effective date of the contract, and for the duration of the contract.

The primary purpose is to document efforts and progress toward completing the performance requirements. The progress report shall be prepared in the form of a letter and shall include but is not limited to a brief statement of the following:

(1) Confirmation of any decisions or understandings reached as a result of technical meetings or discussions with Government technical representatives.

(2) Work accomplished during the reporting period.

(3) Special problems encountered and unsolved.

(4) Percentage of work completed.

(5) Plans for the following month.

1.5.3 Draft Final Report. Three (3) copies of a draft final report documenting the results shall be submitted for review. The report shall include:

(1) data obtained and information generated during the course of the contract.

(2) computations of source segregation effectiveness by source type, in accordance with Section 1.2.3, on a bi-weekly basis.

(3) computations of percentage increase in operating costs attributable to source segregation in accordance with Section 1.4.2.

Comments and recommendations on the draft final report will be retruned within fifteen (15) calendar days after receipt.

1.5.4 Technical Review Meeting. Within fifteen (15) calendar days after receipt of the government comments and recommendations on the draft final report, the contractor shall attend a technical review meeting at CEL in Port Hueneme, CA. The meeting will include a review and discussion of the findings presented in the draft final report and a discussion of the government comments and recommendations. The contractor's representative(s) shall be available at CEL for one (1) day. The contractor will be notified at least seven (7) calendar days in advance of the meeting.

1.5.5 Final Report. Within thirty (30) calendar days after the technical review meeting, the Contractor shall furnish one (1) original manuscript and five (5) copies of a final report. Changes to the draft final report shall be implemented by the contractor in response to government comments and recommendations received and comments at the technical review meeting. The report shall be prepared in accordance with paragraph 1.5.6.

1.5.6 Preparation of the Final Report. The original copy of the final report shall be typed on white bond paper and unbound. Text which does not contain mathematics shall be single spaced, with double spaces between paragraphs, and the right-hand margin shall not be justified. Any graphs, charts or illustration shall be submitted as unscreened glossy, single-weight prints (8" X 10" preferred) on white stock. The original copy shall be prepared in such a form, clarity and definition to allow reproduction by contact copying process. Any drawings, as a minimum, shall be reproducible brown line (sepia). All copies of the report must be legible.

TABLE I BiWeekly Refuse Purity Data Sheet

Date _____

Class of Source (see section 1.2.2) _____

General Remarks _____

_____

% PURITY BY VOLUME

	Paper, Wood, Cardboard Only				No Paper, Wood, Cardboard			
Class*	#1	#2	#3	#4	#1	#2	#3	#4
I								
II								
III								
IV								
V								

Impurity (generally) found in "Paper, wood and cardboard Only" containers _____

Impurity (generally) found in "No paper, wood or cardboard" containers _____

*see section 1.2.1

TABLE II Cost Impact Data Sheet

Date _____

Class of Source (see section 1.2.2) _____

General Remarks _____

_____

	Container Class (see section 1.2.1)				
	I	II	III	IV	V
Labor Time					
Equipment Time					
Other Time					
Type/No. of Personnel					
Equipment Type					
Other Type					
Source*					

Note: Time increments recorded represent transfer time duration of refuse from the class for which the value is recorded to next class for which there is a recording.

*e.g. identification of specific building, areas, docks, or parts thereof.

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